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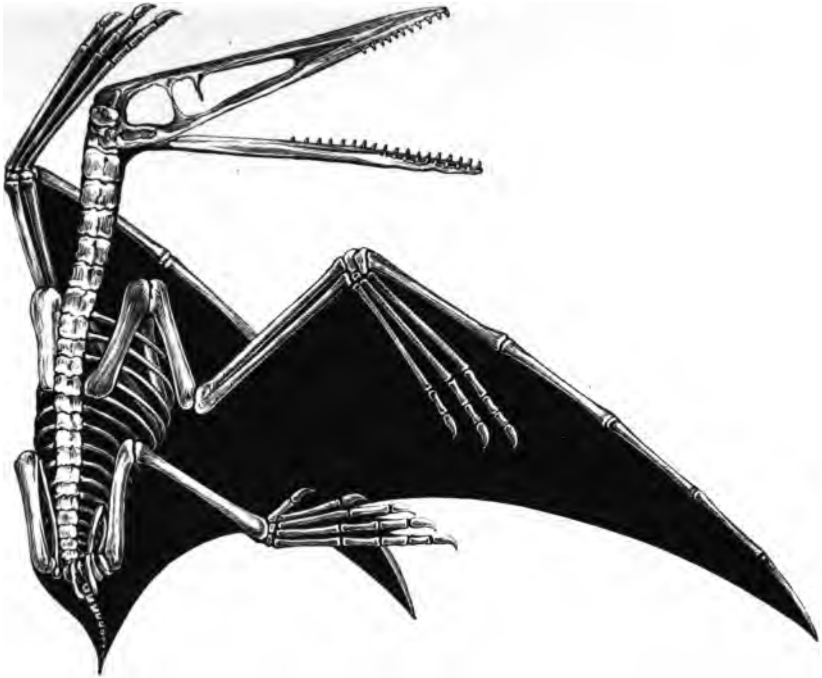
CHAPTERS

FROM THE

PHYSICAL HISTORY OF THE EARTH.

[*Frontispiece.*



Pterodactylus longirostris (restored). About two-thirds actual size.

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CHAPTERS FROM THE PHYSICAL HISTORY OF THE EARTH.

J. C. Russell F.G.S. 1884.

AN INTRODUCTION TO

GEOLOGY AND PALÆONTOLOGY.

BY

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"THE PUZZLE OF LIFE, AND HOW IT HAS BEEN PUT TOGETHER."

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"For wonderful indeed are all His works,
Pleasant to know, and worthiest to be all
Had in remembrance always with delight."

MILTON.

PREFACE.

It will readily be conceded that a liberal education is incomplete without some knowledge of the leading principles of modern science. Accordingly, the more practical and immediately useful of the natural sciences —especially chemistry and physical geography—are now usually included in the regular course of study, wherever it is desired to maintain a standard of education commensurate with the demands certain to be made upon a student entering one of the professions, or aspiring to the higher grades of culture. While so many excellent text-books exist, it might seem unnecessary to add to their number; but such works deal with special subjects, and are for the most part highly technical, rendering it necessary that the varied information they contain should be brought to a focus and directed to the elucidation of the physical and biological history of our planet—an object the author has endeavoured to attain in this volume. Few students or readers find time or opportunity for acquainting themselves sufficiently with astronomical physics, physical geography, biology,

osteology, and anthropology, to work out, unaided, the intimate relation these sciences, among others, bear to geology and palæontology; and therefore it was thought that such assistance might usefully be offered. The work is, in fact, simply an introduction to a subject of undisputed interest, and of the utmost importance to the philosophical student. Little more, it is to be hoped, has been demanded of the reader than a sound general education, which should enable him to follow without difficulty the reasoning by which it is sought to establish the leading principles of geology; and, although it has not been always possible to avoid technicalities, every effort has been made to explain them as clearly as they will admit.

Those who are most familiar with the nature of the work undertaken, will be the readiest to regard leniently any errors of omission or commission that may have crept into it during the collection of materials from so wide a field. The highest authorities have been consulted, and whenever a difference of opinion exists, the controverted points have been set forth. In a few instances, however, such as the avian character of the fore limb in ornithosaurs, Professor H. G. Seeley has been followed; and Professor Henry Huxley's determination of the resemblances between man and the anthropoid apes has been adopted, on the ground that these specialists are carrying with them—at least in principle—the ablest osteologists.

It is hoped that the work may prove useful to the student, and generally interesting, inasmuch as it aims

at presenting a comprehensive outline of the earth's history, from the earliest times to the present, which may be filled up from more elaborate treatises by those who wish to pursue the subject systematically.

The author would, also, be glad if he could hold out a helping hand to that numerous body of intelligent men and women who are striving after self-education with very inadequate means and opportunities, and are compelled to rely chiefly upon the popular scientific lectures which have of late years become valuable aids to education.

In default of references, with which it was not thought either necessary or desirable to encumber the pages, mention is made of all the most important sources whence facts or conclusions have been derived; in order that, while the reader's attention should not be diverted, he might be in possession of the authority for the opinions advanced—the author necessarily holding himself responsible for a correct interpretation of their bearing.

The author would express his obligation to Professor H. G. Seeley, F.R.S., for much assistance in describing the leading structural peculiarities of the ornithosaurian and deinosaurian groups.

A. N.

HAMPSTEAD,
November, 1879.

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PART I.

GEOLOGY.

CHAPTERS

FROM THE

PHYSICAL HISTORY OF THE EARTH.

CHAPTER I.

INTRODUCTORY.

Admirably adapted as man's perceptions are to the ordinary conditions of life, they tell him little or nothing directly of the laws of nature, or the origin of matter familiar to his senses. Certain races of men, who have occupied the earth probably as long as any of their species, are still ignorant of, and indifferent to, the causes of natural phenomena presented daily to observation, but which have never become objects of inquiry or speculation to them. Before man has arrived at an age when he is capable of the simplest reasoning process, he has insensibly learned to accept, as a necessary part of his surroundings, the alternations of light and darkness, the changes of the seasons, and the more obvious results of the law of gravity; but is as little disposed to investigate these as to ask himself why he sees, hears, and

feels. In the history of the growth of human intelligence, however, the starting-point of speculation has invariably been astronomy.

No doubt the beauty and the apparent movement of the heavenly bodies would be calculated to arrest the attention more forcibly than any terrestrial phenomenon; and the observations, however vague they might be, had a practical utility. They became measures of time and direction, sufficiently accurate for the purposes of primitive man; but, as civilization advanced among a people, the necessity arose for more exact standards, observations multiplied, and curiosity gave place to speculation. Ere long, mythology and astronomy joined hands, and priestcraft elaborated an empirical system of predictions and oracles from lunar phases, eclipses, and planetary movements. This was not science, although in this rude cradle it was born. Besides marking the times of religious festivals, the observations were of supreme importance in navigation—their only guides being the sun and stars to so adventurous a people as the Phœnicians, whose voyages must frequently have taken them out of sight of land.

Though the Chinese claim immense antiquity for their knowledge of astronomy, it does not appear certain that they turned their attention to any other branch of science. Even the Greeks, who had distanced all nations in metaphysics (and are yet unapproached in some departments of culture), remained content with a baseless theory of physics, embodied in the belief that the universe consisted of earth, air, fire, and water; and

it was not until the world had lain under the dominion of Aristotle's philosophy for nearly twenty centuries, that any sound conceptions of the fundamental laws of nature began to be entertained. Still astronomy held its place, and discovery had no other domain. Physics and chemistry had not yet emerged from the regions of superstition and fancy; and science was without method, and research without principles, until the master mind of Bacon gathered up the broken threads of all the older philosophies, and wove them into a coherent system. Torricelli taught us how to measure the atmospheric ocean, and Lavoisier analyzed it, while Cavendish discovered the composition of water—starting-points for altogether new departures on the road of investigation.

Now the importance of a knowledge of the constitution of our own planet was fully recognized, and observation and experiment rapidly cleared away the rubbish collected by astrologers and alchemists. Notwithstanding the marked advance in astronomy and chemistry, the interior of the earth remained almost unexplored, and its history a sealed book, until the beginning of the seventeenth century. Aristotle had remarked, in the "Meteorologics," that the distribution of sea and land was not permanent, and vaguely suggested periodic changes in their relations; but his observations applied to local and superficial conditions, leaving untouched the great mechanical agencies which have operated throughout all time. Strabo reasoned correctly—from the presence of marine shells at high levels, earthquakes, and volcanic eruptions—on the movements beneath the surface; and,

had this clue been followed, the leading principles of geology would have been ante-dated many centuries.

Throughout the middle ages, the world, plunged in the sea of theological controversy, found no leisure for the calm contemplation of science; and the best minds were drawn into the vortex which swallowed up all independent thought. Theology demanded concurrence with its own view of the creation of the earth and its inhabitants, under severe penalties; burked inquiry whenever this was possible; and explained away indisputable facts by fanciful theories, or met them by dogmatic assertion. Science owes much to the Reformation. Thenceforward it was not a question of choice between the stake and assertion of the truth of some law of nature; but the human intellect found itself released from the fetters which had so long defeated its utmost struggles for freedom. From the chaotic mass accumulated by astrologers, Copernicus, Kepler, and Newton evolved order in the movements of the celestial bodies; and later, Laplace enunciated the theory of the origin of the universe which we accept, with unimportant modifications, at this day.

The mathematicians had demonstrated the unity of the dynamical laws which governed the movements of all members of the system, and had made new discoveries solely on the faith of the universal application of those laws; and Laplace suspected that bodies, which so rigidly conformed to certain laws of motion, might possess a common composition and origin. Hence the celebrated "nebular hypothesis," which the spectroscope has sustained so remarkably in the hands of Huggins,

Frankland, Lockyer, Secchi, and others. Laplace supposed that all the members of our solar system were the result of the condensation of a greatly attenuated nebulous mass, possibly extending to the utmost limits of our system, eventually splitting up into portions of various magnitudes, and circulating, in proportion to their mass, at different distances from the largest portion—the sun—in virtue of the well-established laws of gravitation. If, then, all the bodies had this common origin, similarity, if not identity, in their composition might be looked for, and has actually been found to exist by modern researches in physics and chemistry. Being no longer strangers to us and we to them [but closely associated in origin and material composition with our earth], the sun, planets, stars, comets, and nebulæ began to assume new interest, and to stimulate new methods of inquiry directed to their physical history, present and past condition, and even possible future. Associated so closely as they had been in their birth, it could not be but they had similar characters in their maturity, and might also undergo dissolution from identical causes. Improvements in the telescope made the interesting revelation that Jupiter, and probably the other most distant planets, were worlds in process of formation; that Mars was in all essential respects in a stage of development comparable to that of the earth; and that the moon had progressed far towards dissolution—conclusions which supported the hypotheses of Laplace. These and like considerations directed stricter attention to the structure of our

own planet—What had been its history since its independent existence?

Modern engineering works, particularly mining, have supplied the answer to this question; but not before many different opinions had been advanced and proved untenable. Passing over the sixteenth and seventeenth centuries—during which we see signs of a desire to penetrate that which was considered a mystery, rather than any systematic efforts to collect and interpret facts —the eighteenth heralded a new era in the inquiry, and the foundation of geology was laid, loosely perhaps as we now regard it, but on intelligible lines. The names of Werner and Hutton can never be remembered but with gratitude; for the very fierceness of the controversy aroused by their conflicting doctrines showed that nothing could be done without patient observation, and extreme caution in generalization while the known facts were so few and isolated. Just before the beginning of this century, William Smith's "tabular view" gave coherence to an undigested mass of observations gathered at random from various sources, and firmly established the principle of the succession of strata and their identification by means of fossil remains.

The progress of the science since then is matter of contemporaneous history—a science adorned by the splendid names of Humboldt, Murchison, D'Orbigny, Lyell, Sedgwick, Mantell, and Hugh Miller, with others who have passed away; and sustained by a body of workers as eminent in research and as conscientious

in investigation as any branch of human knowledge has ever produced.

What is our first impression of the earth? That it is immoveable and unchangeable. Those hills look indeed "everlasting," and oceans and rivers appear to have for ever remained within the same boundaries. But is this so? We feel no motion of the earth, but we know from astronomy that it is spinning round on its axis at the rate of more than a thousand miles an hour, and rushing through space in its orbit at more than sixty thousand miles an hour. We see, then, how very far it is from being immoveable. It is equally far from being unchangeable. The mountains which we look upon towering far above the clouds have not always existed; the oceans have not had the same places. Where land now is, seas and rivers have flowed; and again, where seas and rivers are, dry land has been. All our ideas, then, of the stability and unchangeableness of the earth must be put aside, and we must regard it as the scene of continual disturbance from age to age throughout its long history. Geology has made the story of the earth as plain as astronomy has that of the heavens.

This science is devoted to the study of the origin and classification of the materials of our earth, and of the changes they have undergone in all stages of their formation through the operation of physical forces—such as contraction and displacement, the action of fire, water, air, frost, etc. Geologists designate by the generic term "rock" all these materials, whether they be hard, as granite and lava, or soft, as clay and sand. Each of

them, however, has a specific name, generally derived from some leading character in its composition or the manner of its formation.

Taking a limited view of the surface of the globe, it does not at first appear that there is any great variety of rocks, because they are so frequently concealed by vegetation or overlie one another at any particular spot we may be examining. When, however, we take a wider area into consideration, the variety of them at once becomes apparent. At some portion of the earth one or more of the rocks lies at the surface, and we are thus able to classify them and ascertain the character of the whole of the materials which constitute the globe. At the beginning of this century, very little was known on this subject, and there was scarcely any evidence of the immense age of the earth. Gradually, however, facts have been collected which warrant us in believing that many millions of years have elapsed since the formation of certain of these rocks, and that without the least doubt many thousands of years were occupied in the formation of some rocks of no great thickness comparatively. The reasoning on which these and like conclusions are founded is almost entirely inductive; but it approaches the certainty of demonstration as nearly as any line of reasoning can. Geology cannot claim the precision and exactness of astronomy. Astronomy is based on mathematical problems which, when once stated and proved, are true for all time, past, present, and future; and innumerable proofs of the exactness of this science occur every day. The size, weight, distance,

and other particulars of the physical characteristics of many of the bodies revolving around us are known. We could not attain to greater practical certainty with respect to these if they were terrestrial bodies, and measurable by line and balance. It can be said with certainty, for instance, that a planet *cannot* be more than nor less than so many thousands or millions of miles distant from us, and that it cannot be more than nor less than so many times heavier than a globe of water of equal size. It cannot, however, be affirmed of any rock belonging to our earth that it is not more than so many years old; but it can be said in many cases that it is not less than a given number.

Geologists have come to the general conclusion, from a vast number of facts all pointing in one direction, that some rocks are much older than others, that some were formed comparatively rapidly, and that any one of the series indicates the lapse of a period of time compared with which all historical time is insignificant. Thus any one of the great limestone series of rocks probably occupied a longer time in formation than the whole period of man's existence on our planet. It is difficult to realize these intervals of time, but we can obtain a general idea of them thus: We draw a horizontal line on a board about one-sixth from the top, and another about one-third from the top. The lowest space represents the Primary and Plutonic, or lowest rocks, of unknown thickness; the next the Secondary or middle rocks; and the upper the Tertiary, or latest-formed rocks —designations adopted for the sake of convenience to

denote eras which are not, however, marked by any well-defined boundary lines.

TERTIARY, or Upper Rocks.
SECONDARY, or Middle Rocks.
PRIMARY, or Lowest Rocks, of unknown thickness.

The two upper may be, roughly speaking, from fifteen to twenty-five miles thick, taken together; and the whole of these consist of the *detritus* (worn material) of the older

rocks, with animal remains originally deposited in seas and fresh-water lakes, etc., and of masses of compressed vegetation. Does it not appear, then, on the face of it, that the formation of these latter rocks must have occupied an enormous time? We are dealing with no hypothesis here—we are on the ground of indisputable fact. These latter rocks have been *measured*. This must be taken for granted now. It will be explained subsequently how it has been done.

By a simple but thoroughly scientific process it has been computed that many millions of years have elapsed since the first of these Secondary rocks began to be formed. We need not enter into particulars now, but it may be explained shortly how this has been arrived at. It can be ascertained with tolerable certainty, and has been done for many of the great European rivers, what quantity of solid matter—worn rock, material, and vegetation—is brought down annually by a river. Working together the data for England and Wales, it has been shown that the rainfall over that area would occupy 13,000 years in removing from the surface a single foot in depth of earth—to be carried away and deposited elsewhere.

None of the calculations of these periods is *exact* probably. We can only say that they are, in many instances, more likely to be under than beyond the truth. All such estimates are of necessity founded on the rate of wear and tear going on now, because we have no other means of measuring the action of water; but we must remember that there is evidence of much more

rapid water action in some past times. The impression still remains, however, that no such limit must be placed to the age of our earth as we were accustomed to assign to it before geology became a science, and the facts collected were arranged in order by the great teachers of it.

There is another form of evidence for the age of these deposits, which we may call the organic proof.

Chalk (one of the Secondary rocks) is composed of (chiefly) carbonate of lime, mainly derived from the dead and fossil bodies of small shell-fish called *foraminifera,* from the number of chambers in their shells (Latin, *foramen*, a chamber), and corals. Now exactly the same process of formation of Secondary rocks is going on to-day in the great oceans, notably the Atlantic and Pacific, and even in high latitudes. Incalculable numbers of these little creatures are living at or near the surface, where they assimilate the carbonate of lime suspended in the water, die, and shed their minute shells upon the floor of the ocean. A grey ooze or mud is thus formed, in all essentials identical with chalk, and it *is* the chalk of the future. In the chapter on sedimentary rocks the process of deposition will be more fully explained. We must surely allow an immense time for the deposition of rocks in this manner, hundreds of feet thick, and distributed all over the world.

According to their structure, all rocks may be divided into two great classes—the unstratified and the stratified. The unstratified have been formed, to a great extent or wholly, by the action of fire, and include the granites,

lavas, etc. These show no sign of having been deposited in water, and contain no "organisms"—*i.e.* nothing which ever possessed life, either animal or vegetable. They are more or less crystalline in structure, are excessively hard, and do not split easily. The unstratified rocks, which are at the bottom of the lowest division, are the oldest of all; and this will be apparent when we think of their origin.

Astronomers tell us that the earth is possibly a portion of the sun detached from the parent mass and hurled into space, and now revolving round the sun in its own orbit. It was, doubtless, at the earliest stage of its independent existence, in a state of intense heat, and its materials in a molten, if not a gaseous, state. As the new planet gradually lost heat, the surface contracted, and the rock material crystallized into a form which may, perhaps, be represented by granite. We may regard the earth at that time as consisting of a globe of molten material, covered with a crust of rock which had cooled down enough to become crystallized. This has since undergone great changes, by which the present beautifully diversified contour of the surface has been brought about. Greatly as the earth must have cooled down since its separation from the sun, there is still plenty of evidence of the present existence of intense internal heat. The volcanoes in various parts of the world testify to this; and the lava they cast up, and which runs down their sides, in some cases forming rivers many miles long and broad, and hundreds of feet deep, is melted rock matter derived from the mass

beneath, which has probably never before been crystallized. We may consider volcanoes the outlets of the expansive force of the internal heat, and, as it were, the safety-valves without which earthquakes would cause vast rents in the surface. Many volcanoes have long ceased to emit lava, and some have become covered with stratified rocks. All this indicates a gradual loss of heat, because so many of its outlets have become closed. But from the appearances we observe it is possible to form a very clear opinion of the forces which have operated in former times. Destructive as these fires are even now whenever they break forth; while the unstratified rocks alone existed the surface of the earth must have been in a continual turmoil with explosions of steam and gas, and shaken with mighty earthquakes. Fortunately these convulsions are now limited to a comparatively small area, otherwise vegetable and animal life would be impossible. The gradual diminution of this violent eruptive force prepared the way for the action of water in forming the next series of rocks—the stratified—at whose history we may now just glance.

We have passed from the more violent periods of geological action, when the forces were mostly derived from *within* the mass of the earth, to those quieter times when the *outward* influences of air and water worked changes not less mighty and far more interesting, when vegetation began to clothe the surface, and lowly forms of animal life inhabited the salt and fresh waters of a world progressing towards order, organization, and beauty.

The stratified rocks were formed from the unstratified by various physical agencies, which will be described subsequently. We cannot too firmly impress this upon our minds, that the unstratified rocks have been the parents of all others. What a period of time this opens to our view! All that fifteen miles or so of Secondary and Tertiary and a great part of the Primary rock has been built up of the worn particles of the lowest series! Water, air, heat, and cold have acted upon them incessantly, until an immense accumulation of *detritus* has resulted, and this has been arranged and rearranged by oceans and rivers, and worked into a form capable of supporting life. The stratified rocks, then, are the sediment of the unstratified, and among them are the specially organic or "life-formed" rocks. They are called stratified, from the Latin word *stratum*, spread out; and they are usually capable of being split in certain directions. This is the "line of cleavage," and slate, sandstone, and chalk are familiar examples of stratified rocks. They have generally been laid down in water, and almost all of them contain animal or vegetable remains in more or less abundance. Included among them is coal—the fossilized remains of dense forests which usually grew in marshy situations.

From these rocks we learn the marvellous history of *life*. They are the records, which nothing can falsify, of a steady progress under eternal laws from lower to higher forms of being. Any one of us with sufficient diligence can read these records. They tell us that the earth has been the scene of life and death, pain and

pleasure, for incalculable ages. The plan has ever been the same—immutable as the laws of matter—but it has been expanded by gradations, always, as far as we can judge, tending towards a higher order of things. Geology tells us, in unmistakable language, that the land and water have changed places repeatedly, that continents have sunk, that oceans have been filled up, that both inorganic and organic rocks have been raised into mountain chains, that there has been a long succession of forms of life appearing and disappearing through cycles of time whose vastness we cannot fully comprehend. Thousands of years must be as seconds of time to him who would compute the earth's age, and whole species and genera of plants and animals are but so many finely graduated marks on the great scale of life-duration.

It will naturally have occurred to the reader to ask, "How have the relative positions of rocks been ascertained?" The question cannot be answered in a few words, but it will become more plain as we proceed. There are two kinds of evidence for the succession of the rocks—or, taking several kinds together, "formations" —the natural and the artificial. Nature has herself opened the book of geology, and shown us the arrangement of its pages. Rents and fissures of great depth and extent have occurred in the surface; the ocean has battered away portions of the shore, leaving cliffs exposed; rivers have cut deep channels through the soil; the melted rocks have been thrown out by volcanoes; and in these situations the arrangement of the formations

can be more or less well observed. By means of mines, well-borings, and cuttings for railways, canals, docks, etc., we have made sections of the earth at various points, and much valuable knowledge has been gained by these artificial works. We find considerable irregularity, it is true, in the layers, or "strata" as we shall now call them, thus exposed to view, and they are at some spots much twisted, tilted, and broken, and frequently overlap one another; but by observing a great number of these natural and artificial sections, we obtain a very fair general idea of their relative positions. If we call the formations, from the lowest upwards, A, B, C, D, etc., we may find any one of them wanting at a particular spot, but we shall not find D below C or A above C, though some of the lower may have broken through the upper, and there may have been other accidental displacements quite independent of the order of their formation. For instance, calling granite A, it has broken through B, C, and D at many points all over the world, but its base still lies beneath the others. There have also been subsidences of the strata, and then the edge of one rock may have been pushed over the other; but it is always possible to ascertain on examination that the older rock has been forced above the newer, and was not formed there. The natural order is never inverted.

We know of no part of the earth where a section would show the formations complete. One or more would probably be wanting; but it can be safely affirmed that, if we went down deep enough, granite or rocks of like character would be found at the bottom of the series

at every point on the globe. The order of succession has been deduced from comparison of a great number of observations made in widely different places, and thence has arisen a classification of the great divisions, formations (or groups of rocks), and individual strata, upon the general correctness of which geologists are quite agreed.

The geologist deals with the history of the earth in much the same manner as the historian treats that of mankind. Each classifies and groups the subject under periods and systems possessing broad characteristics. Ancient, Mediæval, and Modern in human history thus correspond with Primary, Secondary, and Tertiary in geology. The historian traces the gradual development of civilization under various dynasties; while the geologist devotes his attention to the formation of the solid materials of the earth, and describes the living creatures which have successively occupied it. Geological classification is to some extent arbitrary and artificial, but it serves to generalize certain natural conditions, and affords a convenient standard of reference and comparison—at least sufficient for all practical purposes while our knowledge is yet incomplete. With respect to chronology, geology is confessedly uncertain. We are compelled to go back from the present through epochs and cycles of time ever extending into a still more distant past, until figures fail to convey any impression of our remoteness from the beginning. Attempts, based on very careful calculations, have been made to assign an *extreme* limit to geological time. By one of the most recent of these, Professor S. Haughton arrives at two

hundred millions of years! Obviously a calculation of the age of one formation is more likely to approach the truth than that of the whole series of rocks; because we are dealing with that formation alone, and can place greater confidence in the data derived from and applied to itself than when these data are applied to several other formations of similar but not identical composition. The measures which may be fairly trustworthy in the one instance can only be *assumed* to be applicable in others. Examples of such calculations and their results will be noticed subsequently. For the present it may be remarked that historical time has afforded very slight opportunities for estimating geological time; but assuredly the former is an insignificant fraction of the latter.

Such is a short outline of the subject, and it will have prepared us to consider the evidence for the now established truths of geology. We shall begin with the unstratified rocks, passing through the stratified series, examining the origin and mode of formation of each, with all the physical forces which have shaped them, pausing here and there to note the fluctuations in the tide of life, and finally arrive at the surface, over which is spread a world of grandeur and beauty—the youngest born of many such lying buried beneath us.

The second part will be devoted to the history of vegetable and animal life upon the earth from the earliest times, and the succession of lower and higher forms throughout the whole series of rocks, illustrated by descriptions and figures of the fossils characteristic of each formation.

CHAPTER II.

THE UNSTRATIFIED FORMATIONS.

Theories as to the earth's origin—Inferences drawn from astronomy—Observations with the telescope and spectroscope—Plutonic, igneous, metamorphic, and unstratified rocks generally—Their origin, structure, characters, and position in the series—Affected by contraction, upheaval, and intrusion among other rocks—Consideration of the present condition of the earth's interior, and the forces still in operation beneath the surface.

It needs hardly be said that the further back we carry our investigations into the world's history, the less confidently we can rely upon them. Various hypotheses have been advanced to account for the existence of our planet in the first place, and there are differences of opinion on its early condition. It will be best, however, to avoid discussion of these hypotheses in detail, and consider that alone which appears most probable and has become generally accepted.

Assuming that at some immensely remote time the earth did not exist as an independent body, its derivation from some other and larger mass of matter is the only conclusion possible. Its parent may have been the sun. Our system is so compact and inter-

dependent, the sun controlling the motions of all the members of the system, that it is not easy to imagine the earth coming into this system as a stranger from distant regions. It is far more probable that it is a portion of the largest and central body, the sun, than of any other. Or we may consider each member of the system to have been a vastly extended mass, which has gradually contracted to its present size.

The earth, then, in common with other planets, may be supposed to have passed from the condition of a gaseous to a highly heated fluid mass, and to have finally become plastic, and moulded by revolution on its own axis to its present shape. This shape is that of an oblate spheroid, *i.e.* a globe flatter at the poles than at the equator. Thus, a straight line drawn through from pole to pole, will be about twenty-six miles shorter than a similar line drawn through from one side to the other at any opposite points on the equator; or, more briefly, the polar is shorter than the equatorial diameter. Now this is indisputable, and in connection with it it is worthy of notice, and can be shown by mathematics, that any plastic body revolving on its axis must, and actually does, assume the form of an oblate spheroid. We cannot but be impressed by the significance of this fact. The polar diameter of the earth has been proved, by numbers of measurements of the surface, to be shorter by so many miles than the equatorial diameter; and any material turning on an axis, and sufficiently plastic to allow of its yielding to centrifugal force, must take the same form as the earth

is known to have. Here is a physical law of universal application; and, when we find that the earth is of the form which such a law always imposes, we cannot resist the conclusion that its materials were semi-solid or plastic at some period of its existence.

Some astronomers regard the building up to a considerable extent of the earth by accretion as probable; considering her as a glowing mass of gaseous vapour, giving off light and heat like a sun, she attracted similar masses of matter from space, and gathered these in to her own body while crossing their paths of circulation. Since, as we know, there is now a yearly increase of her volume, amounting to many thousands of tons of meteoric matter so attracted, the quantity received may have been immensely greater in the earlier stages of her formation, when space was, so to speak, more densely occupied by fragments of matter too small individually to be of any importance, but when gathered up by a larger body, sensibly increasing its size.

Passing outside the boundary of our planet, something is gained by observation of the surrounding bodies. The two great instruments used in these observations are the telescope and spectroscope. Beginning with the nearest of the planets, our satellite, the moon; what does the telescope teach us with respect to it? We can look upon the irregularities of its surface as upon a distant landscape. Any building as large as St. Paul's Cathedral would be distinguishable. Accurate charts have been made of the mountains and valleys, and the numerous craters of extinct volcanoes have

received distinct names. There is no appearance of cloud or water in any form; ice, snow, vapour, and seas are absent; and there is no refraction of light; consequently it is inferred that the moon has no atmosphere, or, if it has, it is in no way physically or chemically similar to that which surrounds us. The moon, then, has all the characters of a burnt-out cinder; a dead world without air, water, vegetation, or animal life; subject to a temperature above that of boiling water during its day, and below zero at night. That the moon has, at some immensely distant period, been the scene of intense heat and violent volcanic action, there can be no doubt. It is one of those bodies which, if it ever had a period of fitness for life, as we understand it, has long passed through that, has lost all its original heat, and is now an interesting ruin, with no apparent relation to us, except as one of the controllers of our tides, and a reflector of the sun's light to us during certain nights of each month.

Now we turn the telescope to a more distant object, Mars. Though this planet is some 50,000,000 miles from us when at its nearest, the positions of seas and continents can be distinctly traced, at least on its southern hemisphere; and the snows upon its poles shine with dazzling whiteness, and decrease very perceptibly every year at a time corresponding with our midsummer, increasing again in the winter. Clouds, driven by strong winds, appear on its surface; and altogether its meteorological conditions are very similar to ours. Here, then, is a planet on which life is possible,

if not probable; and which no doubt retains a portion of its original heat, perhaps equal to that which remains to us.

If we probe the depths of space still further, we come to planetary bodies of vast size. Of these Jupiter may be taken as an example. Eleven times the size of the earth, he ranks as the king of planets. He is 360,000,000 miles from us, but the telescope still reveals some particulars of the physical conditions under which he exists. Many observed facts tend to the conclusion that Jupiter has an atmosphere and clouds. His density is about one-fourth that of the earth; hence the matter of which he is composed is not nearly so compact. His poles, too, are much more flattened than ours; his internal heat may thence be inferred to be much greater than ours.

Astronomers regard these planets as typical of three classes: the moon as one which has passed through all its periods—the gaseous, plastic, and solid states, and is now a dead world; the earth and Mars as in the solid state, when life is possible; and Jupiter as one not yet arrived at maturity, nor sufficiently cool for the habitation of organized beings.

The fixed stars, of which the sun is that nearest to us, have intense heat, and shed light around them upon worlds whose own heat has in a great measure been lost. The spectroscope has revealed the composition of these stars in a striking manner. It is not necessary to enter into details of the working of this instrument, but we may glance at the results obtained from it. The

analysis of light coming from various sources is made by means of specially arranged prisms. Every known substance gives out light if intensely heated, and each has a characteristic spectrum or arrangement of colours by which it is always to be recognized. Thus, for instance, if we vaporize a metal and examine its spectrum, the arrangement of the lines is found to be constant; and so on with other substances. When, then, the spectroscope is used to analyze the light of the sun and other stars, coincidences with the spectra of substances familiar to us, and entering into the composition of our earth, are observed in the light coming from them; whence we conclude that these substances actually exist in the atmosphere of the sun and of those other stars in a state of vapour. Several of these have been determined, and others suspected; but astronomers are agreed that iron, copper, zinc, sodium, barium, nickel, and calcium, and the gases hydrogen and probably oxygen, are component parts of the sun; and that other stars have a varied but not very dissimilar composition. The telescope and spectroscope thus afford us evidence of physical and chemical conditions, in the bodies around us, both similar to and dissimilar from those affecting our earth. The difference in physical conditions is accounted for partly by differences in the stages of existence, and the similarity of chemical composition by the supposition of some common origin.

Assuming the earth, when it began to take a definite form, to have been in a state of incandescence, the denser materials composing it would gravitate towards the centre,

and we should have a semi-plastic mass surrounded by an envelope of gases and watery vapour. The gases would be disposed of in various chemical combinations, and the watery vapour would be condensed into seas when the surface had become sufficiently cooled. The outer crust would then probably be composed of granite, or rocks of like character; and this crust would still be subject to violent dislocations and eruptions, by water finding its way through fissures to the heated interior and giving rise to steam of great expansive power, and by the violent escape of gases. Inequalities of surface would be thus produced, and the foundation of the irregular contour laid. It is quite possible that mountain chains, many thousands of feet high, may have been thus elevated; and, though they would then be extremely rugged, their present comparative smoothness of outline is due to the subsequent action upon them of air and water during a vast period of time.

Whatever difference of opinion there may be among geologists on the *origin* of the rocks of the unstratified series, now to be described, there is little doubt that they have at some time been subjected to intense heat; hence they are called Plutonic, from the mythical god of the infernal regions. Granite may be taken as an example. It consists principally of quartz, mica, felspar, and hornblende; but it is not certain how these minerals became associated together. Heat played an important part, enormous pressure another, and possibly water a third, as is inferred from a microscopical examination of thin plates of the rock. Granite is so commonly used

for building and paving that it needs no description, and it is of various colours, as grey, reddish or pink, and nearly black. That it underlies all other rocks is very probable, but that it has been pushed through and above other rocks at various periods of the earth's history is certain. Some of the grandest mountain chains of the world are mainly composed of it—as the mighty backbone of North and South America and portions of the Alps, and, in the United Kingdom, the Wicklow Mountains, the Grampians, and the high hills of Devon and Cornwall. Regarding these mountain chains as having the general form of a triangle standing upon a broad base, with various other rocks leaning against its sides, the granite base most probably extends beneath them all until it comes into contact with the material below the more solid crust, its presence at the surface far above the general level being due to those forces of upheaval which will be more fully considered subsequently.

The crystalline character of granite, syenite, and others of this class distinguishes them at once from volcanic or eruptive rocks, sandstones, slates, etc. Their materials are irregularly interlaced together without definite arrangement and in very unequal proportions. Whatever doubt there may be of the exclusive or leading part played by fire in the formation of the granitic rocks, there can be no doubt about its sole influence in producing the true *volcanic* rocks. These are distinctively igneous or fire-formed. In very remote times, as in the present—and there is reason to suppose with much more energy formerly than now—melted earth-matter has been

thrown out by volcanoes or through fissures, and has penetrated overlying strata in streams and beds, and squeezed itself into crevices, forming veins and dykes. Such vast quantities of this molten matter are, even in our day, being cast up, that we are justified in attributing still more considerable changes in the strata to its influence in former times, when the forces at work were presumably more energetic. For instance, during an eruption of one of the great volcanoes of Iceland—the Skaptur Jokul—in 1783, two streams of lava were ejected, one of which was fifty miles long and fifteen broad at some points, while the other extended to a length of forty miles, with a breadth of seven at its widest point, and the accumulation was 500 feet deep. On so comparatively small an area as the island of Hawaii, a lava stream, sixty-five miles long and in some places ten miles wide, was formed in the year 1855. Similar instances are furnished at frequent intervals by the volcanic regions of Japan and Central America. There is no difficulty, then, in comprehending the effect of such a heated mass upon any rock with which it may come into contact.

Among the older formations chiefly occur many rocks which are termed "metamorphic" (Greek, *metamorphōsis*, change of form), and are believed to have undergone considerable changes, principally through the action of heat and pressure. Some of them present the appearance, on microscopic examination, of having been originally laid down in water, perhaps *boiling* water, as a sediment, and of having afterwards

been altered by intense heat, and partly or wholly crystallized. Such are quartz and gneiss, and some slates and marbles. Granite is a very doubtful subject. Some geologists think it may have taken its present form under the influence of heat and pressure alone; others that it is the crystallized product of water-formed rocks, since completely changed in character by mechanical and chemical action. We cannot reproduce in our laboratories the stupendous effects of the weight of thousands of feet of rock and the great internal heat of the earth at depths at which these changes have taken place, but the probability of this origin of these rocks may be inferred from experiment. Of this at least there is no doubt, that some limestone rocks have become entirely crystallized at the points of contact with igneous rocks, while preserving elsewhere the evidence of their stratification or deposition in water, and they have become squeezed into fissures in surrounding rocks in such a manner as to suggest their having been melted or rendered pasty while under the influence of great heat and pressure. A complete proof of the alteration or "metamorphism" which has sometimes taken place, is found in the fact that strata containing well-preserved marine fossils—shells, corals, etc.—and therefore certainly sedimentary, have become changed into crystalline marbles in the neighbourhood of such rocks as have been undoubtedly themselves melted by heat. Metamorphic rocks are often found at or near the surface of the earth, as in North America, Scandinavia, and the Scottish Highlands; but they were, in most cases, not formed there—they have

been raised by internal elevating forces to their present position. Rocks which were once sedimentary, as the changed limestones before mentioned, and have since been metamorphosed, must evidently have been at one time at the surface and covered by water; and when that stage of their existence had passed, they were lowered by subsidence till within the influence of heated rocks, or the melted rock was ejected from below over and around them, destroying their former sedimentary appearance. Quartz was thus probably a marine sandstone before its gritty, silicious particles were fused together; and many of the denser sandstones, which still retain marks of stratification, and whose angular particles are quite distinct under a lens, have been cemented by some degree of heat.

One of the most remarkable of volcanic rocks is basalt, which frequently assumes beautiful columnar forms of hexagonal structure, due to contraction while cooling, and is also found amorphous, *i.e.* without definite form, in vast sheets, and as rugged rocks. On the coast of Antrim and in the island of Staffa, the columnar form may be seen at its best; and there are some fine examples on the Rhine, between Coblentz and Bonn. During the process of cooling, the rock appears to form into a number of spheres which, on further contraction, become aggregated into six-sided pillars, in length from a few feet to 150 feet in exceptional cases. The mineral constituents of basalt vary; but iron, silica, alumina, lime, magnesia, etc., are usually present, and the rock is more or less crystalline.

The chemical composition of rocks must be studied elsewhere; we are merely considering now the mechanical and other forces concerned in the actual formation of them as they appear to the eye. They are principally aggregates of sulphates, carbonates, and silicates, associated with oxygen, which constitutes, in its multiform combinations, about one-half of the solid matter of the earth visible to us; and the endless combinations, disintegrations, and recomposition they have undergone present us with innumerable beautiful and useful forms.

With respect to the present state of the interior of our globe there is much difference of opinion; but all agree that the internal heat is still intense. After the first hundred feet from the surface, the average increase in temperature for every fifty feet of descent is 1° Fahr., and this would bring us, at a depth of 125 miles, to a heat sufficient to melt most of the rocks. Volcanic matter, then, may come from deep-seated and perhaps isolated reservoirs of molten matter, steam being generated at high pressure acting upon the roofs of these subterranean caverns, and forcing the lava to the nearest outlet. The magnetic poles of the earth are changing their position in such a remarkable manner, that some have even inferred from this the existence of a solid central globe, rotating at a different rate from the exterior, with an envelope of fluid matter between itself and the fixed outer crust.

Leaving these speculations aside, there are abundant evidences of the operation of enormous forces, in both

past and present times, by which rocks of all ages have been raised and depressed, crumpled, distorted, broken, intruded among each other, and forcibly compressed. Violent and rapid the action has often been; and, again, tranquil and long-continued elevation and depression have produced some of the most important changes of level. Water, in the forms of seas, rivers, rain, and ice, has, however, been the chief agent in the arrangement of the *stratified* rocks, the determination of the lines of the present surface, the direction of valleys, and the physical geography of the visible portion of the earth.

A view of the condition of the interior of the earth has been propounded, which, since it has received the support of Sir William Thomson, among others, demands attention. This view supposes the whole globe to be practically a solid mass, and the liquefaction of rock in volcanic eruptions to be due to the extreme friction of rocks moving and grinding together by contraction at no very great depth. The heat generated by this movement is assumed to be sufficient to reduce great quantities of rock to a melted state, when they are ejected from below. The theory of the older geologists, viz., that the solid crust of the earth is comparatively thin, and that all beneath is still in a fluid, molten state, has now, to say the least, become very much modified.

Experiments for ascertaining the mean density of the earth have proved that the density of the interior is more than double that of the exterior and visibly solid part; and we are thus left to conceive of a fluid (if fluid it be) actually more dense than a solid such as granite!

We have no example of the effect which the pressure of the superincumbent mass may exert upon the matter situated at the centre of the earth, because it is beyond our power to produce such a pressure. The best Aberdeen granite is crushed by a force of nearly five tons on the square inch, but the pressure at the centre of the globe must certainly amount to 13,000 tons on the square inch; and, as Sir G. B. Airy has remarked, "it is an astounding thing to imagine what the consequences may be." The scientific world has lately looked on with astonishment and admiration at the beautiful experiments by which MM. Cailletet and Pictet have reduced oxygen and hydrogen gas and atmospheric air to the liquid state by means of intense cold, combined with a pressure of two tons to the superficial inch; and with such a result before us, we may concede anything to the pressure at the depth of 1000 miles below the earth's surface. Indeed, M. Tresca's experiments show that cold iron and other solids flow with the facility of liquids under sufficient compression.

In considering the large group of unstratified rocks, we can do little more than offer suggestions as to the mechanical and chemical forces which have moulded them into existing forms. Heat and pressure may be counted among the most certain agencies; but we have no measure of the intensity of these in remote times, neither can we estimate the effect of chemical action extending over vast periods, while the chaotic mass of the earth was taking definite form by the arrangement of its materials, and the unstratified foundation, on

which the whole of the stratified rocks were to be built, was being laid down. The serene aspect of the surface at this late period of its history—our own time—suggests nothing of the turbulence and unrest which accompanied the gathering together of the constituents of a granitic rock when the earth was young.

Geology would be a worthless and totally uninteresting study were we compelled thus to rest upon conjecture in all cases, and had we nothing more tangible than speculations on the origin of a rock composed of crystals of quartz, mica, and felspar, or that of a half-baked limestone. From the moment, however, when water began to deposit fragments of the older rocks as a sediment in seas, lakes, and rivers, the evidence becomes clear, and leads to conclusions of the highest interest, which can be verified at every step.

CHAPTER III.

THE STRATIFIED FORMATIONS.

The stratified rocks, their origin, structure, and characters—The process of stratification in rivers and lakes—The Rhone and Lake of Geneva—The Amazon—Oceanic tides, currents, etc., agents in stratification—Deep-sea deposits—Clay and chalk in the Atlantic and Pacific Oceans—Table of stratified formations—Examples of thickness of strata—Breaks in the succession and "unconformability" of rocks—Chemical action.

The term "stratified," applied to the second leading division of rocks, sufficiently indicates that they have been spread out by the action of water, whether the immediate agent was an ocean, a lake, a river, a glacier, an iceberg, or the gently disintegrating force of rain. As soon as the earth had cooled sufficiently to permit condensation to take place in the watery vapour surrounding it, the ceaseless wear and tear of the surface, which has accumulated so vast a mass of material, began. From the dense canopy of vapour hanging over the earth—through which the light of the sun did not penetrate perhaps for long ages—were poured volumes of water, in comparison with which our heaviest rainfall is a mere drizzle; and this continued without intermission, until permanent terrestrial reservoirs and lines of drainage

into them had become established, and the new order of geological action—stratification—which was destined henceforth to determine the contour of the surface and provide the conditions of life, came into operation.

Our only guide to a knowledge of the past is observation of the present; but believing, as we are justified, in the uniformity of natural laws, we may fairly employ a comparison with existing phenomena in the interpretation of the past, with some allowances for greater local or general intensity of action. Every appearance presented by a stratified rock can be fully explained and verified by reference to examples under our own eyes; excepting some chemical modifications of the materials, due probably to the long lapse of time and the influence of contact with heated masses under pressure during the progress of stratification, or after its completion. The mechanical structure is, however, the more important, and generally indicates, without doubt, whether the rock was accumulated by an ocean, or river, or by glacier or berg ice, independently of the very valuable evidence derived from the vegetable and animal remains often included in it.

Catastrophic explanations of geological change find little favour now among geologists; but until a more thorough examination of the stratified rocks was made, these were the prevailing views. The oldest theological creeds and philosophical systems assumed the existence of periodical convulsions, and intervals of destruction and reconstruction, attributing them often to supernatural causes. Neither was this unreasonable in the then

imperfect state of knowledge. It was inconceivable that a mighty mountain chain could have been raised by the exceedingly gradual force which we now know has in most cases sufficed; and the power of the Titans was invoked to account for it. The older philosophers were misled by violent local action—the eruption of a volcano or the shock of an earthquake—into the belief that all the grander results of distribution of land and water and alternations of level were produced by similar convulsions on a still larger scale. Thus the earlier geologists were partly under the influence of ancient philosophies, when they devoted themselves to the task of interpreting phenomena never until this century investigated by any strict scientific methods; although it would seem that they should have challenged attention and compelled inquiry no less urgently than the constitution of the celestial bodies.

Though, then, we must no longer attribute the major changes of level to violent disturbance, convulsions have undoubtedly taken place over considerable areas in remote times, and most probably on a more energetic scale than any of which we have present experience; nevertheless the cardinal fact remains that lakes and river valleys have been excavated, and table-lands and mountains formed, by forces operating with remarkable uniformity, regularity, and slowness, while preserving often the minutest structures of plants and animals uninjured. Periods of widely extended and violent disruption passed away with the consolidation of the earlier unstratified rocks, and water took the place of fire in the

new order of things, by which their seamed and scarred lineaments were to be moulded anew, and a totally different and more tranquil aspect impressed upon the terrestrial features.

A stratified rock may be described as an aggregation, more or less compact, of particles separated from a number of others, deposited in layers, and consolidated by pressure, assisted frequently by lime, iron, or silica, as a cement. The particles may be angular or rounded, or a mixture of both. In the sandstones they are composed mostly of rounded grains of quartz and silica; in the limestones, of carbonate of lime; in the slates and shales, of fine mud; in the conglomerates, of rounded, water-worn pebbles, cemented together with finer material; and in the coal rocks, of densely impacted vegetable matter. The colour frequently depends upon the presence of iron in some form, of lime, or the special prevailing tint of the rock from which the particles were originally derived. The coarser the texture of the rock, the more probable it is that it has been deposited by rapidly moving, shallow water; while the fine slates and chalks have been laid down in still, and often deep water at 2000 feet below the surface of ocean or lake. This we can prove by a simple experiment. Take a handful of coarse silt from the roadside, and throw it into a tumbler of water. The larger particles fall to the bottom, while the smaller remain in suspension some time, rendering the water turbid, until they also eventually settle and become a finer sediment, lying upon the coarser beneath; and the result is two strata, not defined by any

sharp line, but disposed according to their relative weight. The mixture may be rapidly stirred for a few seconds, but still the coarse particles will sink and the fine refuse to do so. Let mud be substituted for the silt, and it will be seen how long a time the sediment is in forming, and how necessary perfect tranquillity is. Now change the scene to a river entering a sea or lake. The rushing torrent has brought down with it portions of rock, and quantities of fine and coarse silt and mud. The rocks and pebbles roll along the bottom, producing, as they grind against each other, finer particles, which are carried more rapidly onwards and prevented by the current from settling, leaving behind all the heavier stones and sand, and passing further away into the lake or ocean. Wherever the gravel settles are the materials for a future conglomerate; wherever the sand, of a sandstone; and the mud, settling down in quiet bays or deep places, becomes in time shale, slate, or limestone.

It is very important that the mechanical action of flowing water should be thoroughly understood; therefore, at the risk of repetition, more minute details may be entered into. It is immaterial whether the scale be great or small—the Mississippi or a rill—the manner in which the materials of our future stratified rock are collected, transported, and deposited is the same, and has been the same from the earliest times. On a wet day we may observe any rill running down a road over sloping ground to a lower level, and forming here and there little pools, or miniature lakes, as they actually are. Unless the current is very violent, the stones and

coarse sand brought down by the water will settle near the place where the rill enters the pool, while the mud will sink further away towards its lower end. Multiply the length, breadth, and power of this rill indefinitely, and we have a great river, whose delta of accumulated sand, gravel, or mud spreads over thousands of square miles, and in long ages forms banks extending many miles out into the sea. But let us trace a brook which enters a river, right up to its source in the hills, remembering that it also is fed by innumerable rills, all doing the same work. The deltas of the small feeders may be washed away in an hour, and their channels altered repeatedly in the same time, because the accumulations are so small. But the courses and deltas of the largest rivers must thus also change in the lapse of ages, though months or years make no perceptible difference in the larger mass; and all the destruction, redistribution, and rearrangement of the solid crust of the earth has been brought about slowly by the very same mechanical forces which affect the little pools, rills, and sand-heaps of the roadside in the short space of an hour. We may mark the course of our rill to-day, measure the depth of its pools and accumulations of mud, and to-morrow all will have been swept away; our miniature river has disappeared—on the very spot is the hard rock of the roadway. Thus the surface of the earth has been changed repeatedly; continents have melted away and been replaced by new dispositions of land; rivers and seas have been filled up and others formed elsewhere; vast accumulations of rock have

vanished before the might of flowing water, and their materials laid down anew by this unceasing process of destruction and reconstruction.

As we stand high up among the hills which supply the river with water, we see far away in the distance, winding through the valley, and opening out here and there into broad reaches or lakes, the fully grown stream whose cradle we wish to examine. Around us lie loose earth, angular stones, detached from the hill-side by water penetrating the crevices (in winter the water forms into ice, expanding with the irresistible force of a wedge, and splitting fragments from the face of the rock); and beneath lies rubbish of all kinds, evidently derived from the immediate neighbourhood. At the foot of every gully lies a heap of this *débris*, which will eventually be reduced to rounded stones, sand, and mud, in its passage down the river. On one hand is a greyish limestone rock, through a cleft in which flows a rivulet. This we will follow downwards to its point of entry into the river. All along its course are angular blocks of the stone, of all sizes up to many tons in weight. Some, which have remained there a long time, are polished on the sides by the attrition of passing stones, and others are fairly rounded by being rolled on during floods. The further we go the more rounded the largest blocks and smallest pebbles become, and we find besides a mud of the characteristic colour of the limestone rock. Continually grinding against each other and the bed of the stream, they scoop the channel deeper and wider year by year, and arrange themselves along its course according to

their weight. The boulders may remain for hundreds of years in one spot, but they, too, are wasting away; while the silt and sand go forward more rapidly, to form a bar or delta to the river; and the mud onwards still, to settle in the quiet depths of lake or ocean;—every winter's frost and every shower of rain contributing a fresh supply of material at the base of the hills and gullies which flank the river's course.

A notable example of the transporting action of water is the Rhone. The colour of the water entering the Lake of Geneva is greyish on account of the fine limestone mud suspended in it, and contrasts strongly with the blue water of the lake, in which it settles long before it reaches the outlet. But on both banks at the entrance of the stream are deposits of coarse silt, which have usurped a mile and a half of the lake since the little place called Port Vallais was at the water's edge and was used as a landing-place by the Romans.

Such is the universal type of river action, modified by local circumstances, all the world over. Their channels alter rapidly or slowly, according to the nature of the soil: on the great, almost level, pampas of South America they have moved many miles to the right or left of their course in no very long time; they may become a succession of lakes without outlet, or lose themselves in sandy tracts, or, entering caverns in limestone formations, flow underground for a long distance, and either totally disappear or at length reappear. All those which possess extensive deltas are undergoing a change which must in time greatly modify the physical

geography of the neighbouring country. The contraction of their mouths and the vast accumulations of *detritus* may convert their basins into wide reservoirs, diminishing the force of the current, allowing more of the water to escape by evaporation, and finally extinguishing the outlets to the sea altogether. Then an inland fresh-water sea of considerable extent will be formed, a rampart of dense vegetation will be thrown up on the delta, and the accumulations will henceforth become a fresh-water instead of a marine deposit. Thus probably some of the stratified rocks of ancient times have originated.

Rivers having a broad and deep estuary may be taken as the type of those which contribute the most considerable marine formations, for they carry their sediments far out to sea. At 300 miles from its mouth the water of the Amazon discolours the sea! What must be the amount of material annually removed from the drainage area of this river, extending over 2,000,000 square miles? Sufficient to form a vast deposit in a very short time assuredly. With such an example of water-power before us, we should have no difficulty in realizing the deposition of a sedimentary rock hundreds of feet thick. The Amazon is thus spreading over the floor of what is now the Atlantic Ocean a bed of soil derived from the South American continent, which in some distant geological age will be a stratified rock, mechanically similar in all essential characters to those forming large portions of the existing land.

At low tide on a sandy shore we may observe a perfect system of rivers and lakes in miniature, doing

the work of disintegration and redisposition at a very rapid rate. A few hours' study of such a beach will be of more advantage than pages of description. Here are cliffs, terraces, deltas, and every other form of destruction and reconstruction, effected by the streams running down the gentle slope to the sea.

Having thus briefly glanced at a few instances of the local action of running water, we need only picture to ourselves the mechanical power of the rainfall of the whole world, in order to form some conception of its aggregate effect as it is poured down from higher to lower levels in countless streams, each bearing its burden of soil to some place of temporary or final rest. We may picture the effect of the enormous rainfall about the tropical belt, where frequently 150 inches of rain are precipitated every year upon the parched surface—an amount equal to 15,000 tons of water to every acre. On the mountains high above tropical plains, snow and ice are doing their part, and perpetual frost is splitting fragments from the rocks, to be borne away into the valleys by impetuous torrents from the melting snow-fields. Within the polar circles ice on a more magnificent scale is levelling down the land. Glaciers covering thousands of square miles are slowly sliding down the valleys, grinding them deeper, forming sands, clays, and gravels, and pushing these down to the shore. Icebergs, many miles in circumference, are carried by currents along coasts and against cliffs, scooping channels by their immense weight—gigantic ploughs, which leave their furrows in the bed of the sea.

No one can contemplate the majestic spectacle of a storm by the sea-shore without feeling profoundly impressed by the power displayed in this form of moving water. The mind, however, is more apt to be led away by the poetical aspects of the subject than to contemplate it in its scientific light. If we wish to know what those rolling billows are doing, let us watch them carefully for a few minutes when the tide is nearly high. Every wave, in its onward sweep, is carrying up shingle, gravel, and rock-material of all kinds, large and small, angular and rounded, and hurling it against the base of the cliff, which is cut under, drilled into holes, and battered by the unceasing assault. At the top of the cliff indentations are made by rain trickling down from above. Horizontally and perpendicularly the rock is being disintegrated and worn away. Presently portions of the overhanging mass will fall, and so much more of the barrier against the sea's encroachment is cast into the mill below, where it will be ground down, and in its turn contribute to a new formation. Two agents combine in distributing the soil thus torn from the coast-line; first there is the daily ebb and flow of the tide, which acts with much greater energy on the shallow bottom near land than far at sea; and secondly, innumerable currents, both constant and variable. These rapidly carry the materials to and fro, and transport them long distances. Any fixed projecting object on the bottom, such as a wreck, for instance, will sometimes form a gathering-point, and be covered in a short time. Just as in the case of the river, the heavier stones will

form *beaches* in shallow water, and the lighter settle in more tranquil localities, the former to become conglomerates, the latter densely impacted sedimentary rocks.

Hitherto our attention has been confined to the land and its immediate neighbourhood, where, no doubt, the forces which determine the collection and distribution of the elements of new formations have the greatest intensity. The profound depths of ocean, however, are continually receiving deposits—a fact suspected, but not until quite recently proved. Geologists had arrived at the conviction that some stratified rocks must have been laid down in very deep water, as certain of the clay slates and chalks. In the first place, water was evidently the agent of deposition; and in the second, the immense accumulation and finely divided state of the materials precluded the idea of any conditions but those characteristic of deep and undisturbed water; the remains of animal life, too, included in these rocks pointed to their *marine* origin.

Owing to the progress recently made in the science of oceanic meteorology, wonderful revelations have taken place in the secrets of the great deep. The most recent of the deep-sea exploring expeditions in the *Challenger* has enabled us to survey, as it were, the floor of the ocean by means of the dredge. The results must be touched upon lightly here, for they will be more fully detailed in the chapter on the "organic rocks." In many parts of the Pacific Ocean far from land the depth is over 18,000 feet; in the Atlantic,

frequently 12,000 feet. These are submarine valleys, and they are being filled with new deposits of two kinds—a variety of clay and a variety of chalk; the former being invariably found at a greater depth than the latter. This clay or ooze appears to be formed to a large extent of decomposed pumice-stone (the froth of lava ejected from volcanoes either on land or beneath the sea), great quantities of which are found floating on the sea. The chalk mud is very different in composition, being almost entirely carbonate of lime, derived from the shells of minute animals, countless millions of which are living and dying in these oceans. But the important fact is that we find similar shells in chalk at present on the surface of the earth; whence it is inferred that the chalks now above ground were once laid down in ocean depths. There is no possibility of mistake here; for the microscope and a few simple chemical tests disclose the nature of these clays and chalks brought up by the dredge and submitted to the closest examination. The water must be absolutely motionless in these submarine valleys to allow so fine a sediment to accumulate. This process, it must be remembered, is going on in all the deeper parts of the Atlantic and Pacific Oceans, and we cannot doubt that these are the clay slates and limestones of the distant future, just as those with which we roof our houses are similar representatives of a remote past.

Though not stratified rocks in any of the above senses, coal and like accumulations of fossilized vegetation may be so classed for convenience. They are

at all events very distinct from unstratified rocks, and, besides, frequently present the appearance of layers. Moreover, they are so intimately associated with limestones, sandstones, shales, etc.—all water-formed rocks—and in some cases appear to be merely vast masses of drift vegetation from rivers, subsequently overlaid by sand and mud, that they possess, mechanically speaking, a stratified character. Further, the plants composing many of the beds grew in swamps subject to inundation and even occasional incursions of the sea, and were mixed with various sediments. Consideration of these "organic" rocks must be deferred for the present.

Every stratified rock is of course laid down approximately horizontally; but we shall find that a great alteration has taken place in many instances. Abrupt dislocations and fractures, displacements and contortions, occur in every part of the world. A stratum once horizontal may since have assumed the form of a series of curves or angles; it may have been bent so sharply as to have broken; its edges may have separated, and the interval become filled with a more recent rock. Whenever this is the case, the rock will lie at different angles with the horizon, from the gentlest incline to the perpendicular. How, then, has this been brought about? Simply by the continued action of those internal forces of the earth which crumpled and twisted the earlier unstratified formations, and may be seen in operation at this day on a minor, but still unmistakeable scale. Veins of metallic ores have been pressed into fractures and crevices, and molten volcanic rocks

squeezed through, over, and around our formerly horizontal strata; but there still remain undisturbed tracts in abundance, from which the history of vegetable and animal life can be told with quite as much practical certainty as if these disturbances had not occurred.

The order of succession of the stratified formations (or groups of rocks) is seen at a glance in the following table, where the oldest are at the lower end of the scale, and the newest at the higher:—

TABULAR VIEW OF THE ORDER OF SUCCESSION OF THE STRATIFIED FORMATIONS.

TERTIARY, OR KAINOZOIC.	PLEISTOCENE (most recent).
	PLEIOCENE (more recent).
	MEIOCENE (less recent).
	EOCENE (dawn of recent life).
SECONDARY, OR MESOZOIC.	CRETACEOUS.
	JURASSIC (or OOLITIC), with Lias at its base.
	TRIASSIC (formerly included with the Permian, under the name of New Red Sandstone).
PRIMARY, OR PALÆOZOIC.	PERMIAN.
	CARBONIFEROUS.
	DEVONIAN (and Old Red Sandstone).
	SILURIAN.
	CAMBRIAN.
	LAURENTIAN (and Huronian). Highly metamorphosed rocks.

Some explanation of these terms is needful, since they will often occur in the following pages.

The great Canadian river, the St. Lawrence, determines the name of the lowest, because this formation was first examined and is most conspicuous there. The next, Cambrian, takes its name from the ancient name of Wales; and the third, Silurian, from the old inhabitants of the country. The fourth, Devonian (and *Old* Red Sandstone), has very strongly marked characters, weaker perhaps, however, in Devonshire than in Normandy and Russia; and is by no means wholly composed of sandstones, but includes coralline limestones and slates. The fifth, the Carboniferous (Latin, *carbo*, coal, and *fero*, I bear), is the principal seat of the coal measures, derived from vegetation. The Permian is at the top of the PRIMARY, and the Triassic at the bottom of the SECONDARY divisions; but the line of demarcation appears to be ill defined as to the character of both the rock and fossils, and the terms include much that used to be known as *New* Red Sandstone. The Oolitic (or Jurassic) is well developed in Dorsetshire and the Jura Alps. This formation is chiefly limestone, marked in England by a singular aggregation of rounded and oval grains similar to the roe of a fish (Greek, *oön*, an egg, and *lithos*, a stone). The Cretaceous (Latin, *creta*, chalk), one of the organic series, is very conspicuous in the south of England, and includes the greensands and gault. Near the base of the TERTIARY lies the clay of the London basin in the Eocene (Greek *ēōs*, dawn, and *kainos*, recent). The Meiocene (Greek, *meiōn*, less, and

kainos, recent) is poorly represented in England, but well in France, Belgium, and the valley of the Danube. The Pleiocene (Greek, *pleion*, more, and *kainos*, recent) contains, among other deposits, coralline crags in abundance.* The Pleistocene (Greek, *pleistos*, most, and *kainos*, recent) is remarkable for its Glacial drift deposits—boulders, clays, and gravels—recent coral beds, volcanic islands, lavas, and ashes; raised beaches and terraces; cavern earths, with extinct animal remains and implements of human manufacture; breccias and caves with human fossils; marls, peat-mosses, submerged forests, and great alluvial plains—as the pampas of South America. This is emphatically the *human* period, marking the advent of man in his most primitive condition.

The three great divisions, PRIMARY, SECONDARY, and TERTIARY, have been named respectively KAINOZOIC (Greek, *kainos*, recent, and *zoē*, life), MESOZOIC (Greek, *mesos*, middle, and *zoē*, life), and PALÆOZOIC (Greek, *palaios*, ancient, and *zoē*, life), in accordance with the distribution and succession in time of the fossil remains included in the various strata grouped in each division.

As noticed in the introductory chapter, attempts have been made to estimate the aggregate mass of these stratified rocks, but the results differ widely in some instances. On the other hand, where a rock crops out,

* These terms indicate in a general way the proportion of fossil forms which belong to existing genera. Thus, the Meiocene rocks contain a *less* proportion of forms referable to existing genera than do the Pleiocene; and the Eocene strata exhibit the *dawn* of types which the Pleistocene formations present in the greatest numbers.

showing its edges over a considerable extent of country, or where a boring can be made through it, the task of measuring it is easy. Lying at the base of all the stratified rocks, the Laurentian formation has been estimated, from its outcrops in North America, to be little less than 30,000 feet thick; and the Silurian of Wales falls not far short of this. Again, the laminated clays and limestones of the Lias alone, at the base of the Oolitic (or Jurassic) formation, are in places 600 feet thick; while a depth of 3000 feet cannot be an exaggerated measure for the whole of the members of the Oolite in England—an estimate which Professor J. W. Judd has recently confirmed by a strict investigation of these strata in the Western Highlands of Scotland. The whole of the Cretaceous formation in England can be scarcely less than 3000 feet, the chalk itself being in some places 1000 feet thick. American geologists give three times this as the extent of the formation in North America. Borings in London have proved the base of chalk to lie about 1000 feet below the surface, and it appears to be 650 feet thick at the junction of Oxford Street with Tottenham Court Road. Even the well-known London clay, deposited while the lower part of the Thames valley was covered by sea water, attains a thickness of at least 450 feet towards the Isle of Sheppey; and there can be no reason to doubt the general correctness of the measurements in these particular cases.

It is difficult to realize the fact that these immense accumulations have been gathered together by water, until the mind has become familiar with the subject; and

still more difficult to form any conception of the time occupied in the process. There is, perhaps, no better plan for arriving at the conviction that they have been thus collected than to visit a chalk quarry, and contemplate the formation steadily. The long parallel lines of flints point clearly to stratification, and the innumerable fossil shells and bones of fishes to life in sea water. A fairly powerful magnifying-glass will often reveal fragments of shells in a small portion of the chalk rubbed into powder and examined on the tip of the finger. No other explanation of these facts is possible than that we have before us the bed of an ancient ocean, and the sepulchre of its once living tenants.

Referring once more to the table of stratified formations given on a former page, it must be recollected that the whole series may not be expected to present themselves everywhere. Some members may be, and often are absent; but they have never yet been found to change their relative positions. Thus, immediately under London, the Oolitic formation is wanting, though the Cretaceous occupies its proper place together with other strata belonging to it. Either the conditions which gave rise to the Oolitic series further west and north were not present in the east of England, or these strata have subsequently, and before the deposition of the Cretaceous, been worn away; as will be explained in the chapter on denudation and erosion. The thickness, too, of a given formation is extremely variable. In one locality we may find it extend to hundreds of feet, while in another it is barely distinguishable. This must necessarily be the

case, since the conditions under which it was formed, and to which it has afterwards been subjected, cannot be assumed to have been uniform all over the globe during any of these periods. As far as is known at present, the British Islands offer the best example of the succession of the rocks, on a line drawn roughly from London in a north-westerly direction to North Wales. Near London we find the TERTIARY deposits, in Hertfordshire the Cretaceous, in Northamptonshire the Oolitic limestones, in Staffordshire the Carboniferous and Red Sandstones, and, when we get into Wales, the Cambrian slates.

Though the *succession* of the rocks is regular and uniform, the strata and formations are not always "conformable," that is, they do not always lie parallel with and evenly upon each other, as they would if deposited without any disturbing influence. This arises from two causes: from disruption of the lower stratum before and possibly after the upper was laid down; and from partial destruction by water of the lower, and subsequent deposition of a new rock upon the uneven surface of the lower. The former effect may be illustrated in an exaggerated manner by placing two books together at an angle, and resting a third horizontally upon them; the latter, by half filling a plain tumbler with red sand, and making a number of depressions right across it, regularly or irregularly, and filling these up with white sand—on looking through the side of the glass, the "unconformity" of the two strata will be seen. The beds of the newer formation rest upon a worn surface of the older, and suggest at once that there must have been an interval of

time between them, during which the lower had been affected by some powerful agent. The lower may be thus partially destroyed or wholly swept away, and that stratum is wanting at that particular spot, as in the case of the Oolite beneath London, previously mentioned. Thus the chalk has undergone much wear in some localities, and the TERTIARY formations rest unconformably in its depressions.

These imperfections, while helping us to understand much of geological action, deprive us of much valuable evidence on the succession of *life*, and baffle all endeavours to make the record as complete as, from various considerations, we are inclined to believe it must be. Our investigations of the strata, however, considerable as they are, are quite insignificant in relation to the entire earth. With our mines and railway cuttings, we are very much in the position of a carpenter who bores a few gimlet-holes into a tree, and is compelled to judge, from the cores extracted, the exact nature of the wood, the mode of sap circulation, and all its life history without any other assistance. The task becomes exceedingly difficult when we desire to present a comprehensive outline of all the changes, both mechanical and biological, which the earth has undergone; and it demands the most patient observation and comparison of isolated facts, with extreme caution in generalizing from them. Fortunately, these qualities are possessed by the great body of workers, so that we may hope for the ultimate solution of many yet obscure problems.

Two other agents in the formation of stratified rocks

—wind and chemical action—may be briefly noticed. On the west coast of India, for example, are long stretches of sand-hills thrown up by the sea, and afterwards further raised by wind-blown sand to a considerable height. Wherever streams have made sections through these, the part played in their construction by wind and water can be pretty accurately apportioned. The deposits which owe their origin to wind are relatively inconsiderable; but not so those, whether formed within or on the surface of the earth, by chemical agencies. The familiar substance known as rock-salt occurs in large masses in Cheshire among the Triassic rocks, and in Spain, Hungary, etc., but it is confined to no particular formation. These isolated masses were no doubt deposited by precipitation during the gradual evaporation of the water which held the salt in solution. In extreme cases, the beds are nearly a hundred feet thick. Limestone districts afford numerous examples of the action of the carbonic acid of water percolating through fissures, and giving rise to crystalline forms of carbonate of lime, such as stalactites and stalagmites in caverns, and tufa and sinter on the margins of calcareous springs. Water holding silex in solution rises to the surface and deposits its burden in a similar manner, and sulphur is an important product of volcanic regions. Though these do not add very perceptibly, except in the case of the travertine beds of Italy, to the solid matter of the earth, they illustrate a form of geological action which must, in the lapse of time, have exercised a widespread influence in dissolving and rearranging rock-masses, more par-

ticularly below the surface, where heat would assist in various chemical combinations.

Although it cannot be termed a rock, as a product of certain kinds of carbonaceous shale, and also the result of some form of chemical or organic action, petroleum or mineral oil demands a passing notice. It occurs in prodigious quantities in the carbonaceous shales of the Huronian, Silurian, and Devonian formations chiefly, in Europe, Asia, and America; but notably the last. In the report of the geological survey of Ohio, published by authority of the United States Government, this oil is spoken of confidently as having an organic origin; being slowly distilled, under heat and pressure, from immense accumulations of the bodies of crustacea and fishes, denizens of the Silurian and Devonian seas. Professor Mendelejeff, of the St. Petersburg University, treats the question from a chemical point of view, and assumes the existence of masses of iron and inorganic carbon in the interior of the earth—water, penetrating to the molten metal, is decomposed, its oxygen passing to the iron, and its hydrogen uniting with the carbon to form the varieties of hydro-carbon which we know as petroleum. The experiments carried out by Cloëz on manganese and iron oxides, containing graphite, and treated with boiling water, suggest a confirmation of this theory; for he thus obtained inflammable gases and liquid hydro-carbons similar to those emanating from petroleum springs.

Ingenious as these speculations are, they should be received with caution. We know that specimens of

shales from the PALÆOZOIC formations are a mere mass of crustacea, and that iron occurs, as well as inorganic carbon or graphite; but we have no direct evidence that the distillation of oil from these organic remains has actually taken place, nor that the chemical combinations involved in the other hypothesis arise in the interior of the earth.

CHAPTER IV.

UPHEAVAL, SUBSIDENCE, AND DENUDATION.

Upheaval, subsidence, and denudation considered in their effects on all classes of rocks—Alterations of level, and contemporary geological action—The cañons of Colorado—Denudation on river basins—Recent volcanic action; appearance and disappearance of islands within historical times—Earthquake waves, geysers, etc.—Raised beaches; terraces of Norway; sinking shores—Conclusions from animal remains.

From occasional former references to the great and frequent displacements which the strata have suffered, the reader will have concluded that there has never been a truly stable and permanent condition throughout the whole history of the earth. The results of oscillations above and below the mean level, ranging from a few inches to several miles, are everywhere apparent. The great difference observable between the summit of a mountain chain and the general level of the ocean—which is always our standard of reference—cannot be accounted for by the agency of water, but must be referred to another cause. Mountain systems may be formed of unstratified or stratified rocks—of granites, limestones, or sandstones—or partially of all; and it is now generally

understood that they owe their elevation to the gradual contraction of the earth in cooling, perhaps supplemented by active volcanic movements. Experiments undertaken to illustrate the effect of lateral pressure in forming these great inequalities, have confirmed this view. Professor Favre of Geneva found that, by subjecting a horizontal layer of plastic clay to pressure from two or more directions laterally, contortions and foldings of the material, strongly resembling mountains, valleys, and other natural appearances of the strata were obtained.

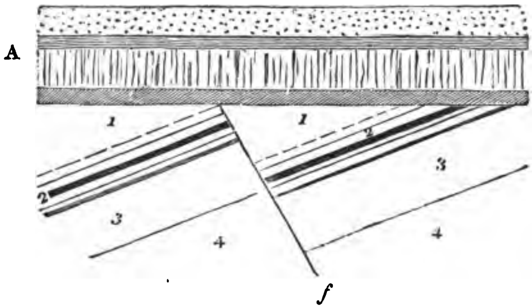

FIG. 1.—Diagram of positions of rocks affected by subterranean actioa. A. Horizontal strata conformable with respect to each other; and resting unconformably on the inclined strata 1, 2, 3, 4, which are dislocated by fault, *f*.

Vaults, dykes, anticlines, synclines, faults, and fissures were represented, often with minute accuracy, by the clay as it yielded to the pressure; and the material was in some instances folded back upon itself, as actually occurs in nature. The sides of the ridges presented steep escarpments and gentle inclines; and, while in some places the lower strata remained horizontal, those

above them were much dislocated. We know the earth to be a gradually cooling body, and in the course of ages it must necessarily contract. The axis thus becomes shorter, and the mass of matter composing the globe is compelled to occupy a smaller space. In accommodating itself to the urgent force of contraction, some portions are pushed upwards, and others, by comparison, appear to have been depressed, and really have in many instances fallen below the normal level. The unequal resistance of contiguous strata contributes to this, and the depressions and elevations are therefore not uniform over the whole surface; for the matter of the globe varies very greatly in density, in both the horizontal and perpendicular directions. Thus, by measuring the undulations of contorted strata between two given points, it has been found that they occupy a space only two-thirds of that covered by them before their compression.

The casual observer, in looking at the sections of Professor Favre's layer of clay after compression, would be struck by the close resemblances they afford to every peculiarity in the structure of a mountain system; and, when tested by measurements, they show how much exaggerated our ideas of mountains are. A ridge 10,000 feet high is really a very moderate and almost inappreciable object on the surface of the globe, when we compare it with the immense diameter and vast superficial extent of the earth. Relatively to ourselves, and to the objects of comparison within the immediate range of our vision, such a ridge appears of stupendous magnitude. But our view of the subject undergoes a complete

change when we measure the original length and thickness of M. Favre's experimental layer of clay, and note the effect of crushing. The ridges raised upon this are frequently one-tenth of the original length of the material operated upon, and the depressions proportionate to them. It is, then, possible that mountains five miles high might be produced on the surface of the earth in an area of crushing or compression no more than fifty miles in extent, with corresponding valleys of great depth, and those extensive "faults," so frequently—indeed almost invariably—observable in mountain systems.

Thus the chains of America, Asia, and Europe have been squeezed up into irregular ridges high above the general level, by the shrinking of the crust. When the mountains are of stratified character (as, for instance,

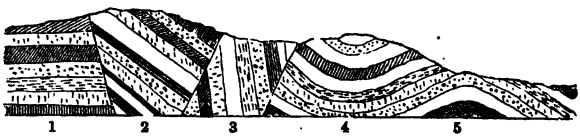

Fig. 2.—1. Horizontal strata; 2. Inclined; 3. Almost perpendicular; 4. Synclinal; 5. Anticlinal.

portions of the Pyrenees and Alps), this "upheaval" must have taken place after their deposition in water, and they are consequently comparatively new. Besides these grand examples of elevating force, there are many of minor extent, but no less significance, stretching along the shores of continents, where the coast is gradually raised, and new islands are lifted from

the bed of the sea; or sea-beaten beaches are left high above the water-line, to testify to their late immersion, by water-worn cliffs and stones, and remains of marine animals. Strata become thus necessarily inclined at very various angles, from an almost imperceptible slope to the vertical; and in the latter case their edges are exposed for thousands of feet, and their thickness is easily measured. Elevation must be compensated for by a corresponding amount of depression or subsidence of some other part of the surface; and the alternation of these two forces has constituted a more potent distributor of land and sea than even water itself—fashioning the rough outlines of continents and oceans, and placing them successively within reach of atmospheric and aqueous influences.

A simple illustration of one form of subsidence will be seen in the following diagram, where D B is the

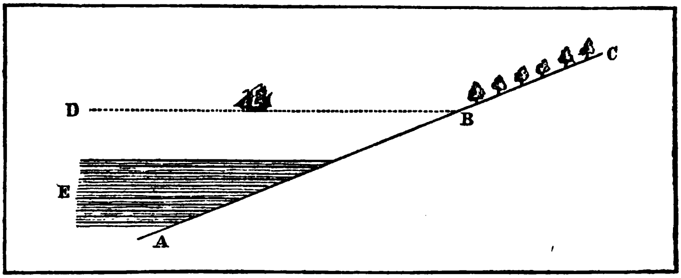

FIG. 3.

sea level, and A B C the line of dip of a stratum whose lower part, A B, is now immersed up to the point of contact of land and water at B; B C representing the

formerly horizontal land slope. Now it is clear that fresh deposits may take place along this immersed line in the general direction of E, whence a new stratum, partially "unconformable" to the other, will be formed. The sinking floor destined to receive this fresh accumulation may be either an unstratified or stratified rock. Subsidences take place over large areas, and water-formed rocks are thus brought into contact with heated matter at a great depth, and metamorphosed, or changed into a partially crystallized form; or in some cases the heated matter seems to have been forced through, around, and over them, but still leaving evidences of their marine origin by the presence of fossils within a short distance of the heating material. After a ridge has been raised by the contraction of the earth on surrounding areas, atmospheric forces begin to act upon it, and the whole series of phenomena—rain, frost, chemical decomposition, land-slips, and rivers—come into play; and in process of time we have a new set of stratified rocks formed along the flanks of the older. It is conceivable that these elevations may take place beneath deep seas, that the process may be so slow as to allow of the collection of masses of material on the slopes of the ridge long before its crest appears above water, the elevation finally reaching a considerable height above the sea level. In this case the flanking strata will be more or less bent and disturbed. Varying so much as rocks do in compactness, we might expect these movements to exhibit much irregularity, and should find it difficult to decide in given cases

whether displacement was the result of subsidence or upheaval. It seems impossible, however, to attribute the general contour to any cause except immense force of lateral and vertical pressure, operating over long periods of time, and proceeding slowly in most cases.

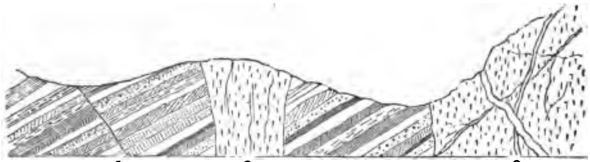

FIG. 4.—1. Fault; 2. Dyke; 3. Lode and mineral veins.

When we reflect that some of the peaks of the Andes, still in a state of active eruption, are at least seven miles above the bed of the two oceans which lie on either side of the chain, we are compelled to infer that the internal force is very unequally distributed; for from several peaks on this ridge fire and lava are perpetually ejected, while a profound sea lies in the troughs on both sides. Actually the difference in level is great, though relatively small, since the depression and elevation combined amount to less than a thousandth part of the diameter of the earth; in fact, less than a covering of thin paper upon an orange. Deep seas are thus in our day areas of greatest, and volcanic regions of least resistance to disruption; but we have no reason to suppose this a permanent condition, for all past experience negatives the idea. Similar areas of greatest and least resistance, with intermediate gradations innumerable, have repeatedly interchanged characters, the higher level taking the place of the

lower, and *vice versâ*. Generally the process has occupied a vast time, but occasionally it has occurred in a few months or days, within present observation.

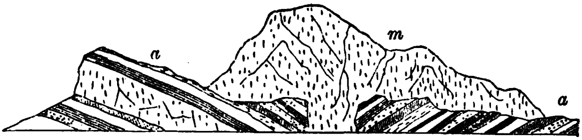

FIG. 5.—*m*. A disrupting mass of unstratified rock overlying *a a*, stratified rocks inclined at different angles.

Such being the leading phenomena of upheaval and subsidence, we may now pass on to those of denudation (Latin, *dēnūdo*, I lay bare), with its supplementary force, erosion (Latin, *erōdo*, I gnaw away). The ordinary denuding action of a river has been sketched previously; and one form of erosion, with subsequent deposition of material on the unevenly eroded surface described; both of which are typical instances so far as they go. Denudation carried to an indefinite extent would evidently at length bring the land to a very general level, but for the constant presentation of new prominences by elevation, and the formation of new depressions by subsidence. A pile of strata thus brought within range of denuding forces, and composed of soft and hard rocks, must wear unevenly, the weak places suffering most; or the rock might be homogeneous (*i.e.* of similar character throughout), and the greatest erosion would occur on the natural primary lines of drainage—hills, valleys, precipices, ravines, and water-courses being in either case the ultimate result. Isolated

hills and ridges have frequently been left standing because their hardness gave them more power of resistance than the surrounding rocks; but they are often, too, thus isolated because their originally prominent position diverted the greater part of the water from them into continuous channels at their bases. In fact, local causes have exerted so much influence that they can only be studied on the spot with any prospect of coming to an exact conclusion.

The Colorado river basin furnishes the most extraordinary instance on the whole face of the globe of the potency of river excavation. The plateau lying between the Rocky Mountains and the head of the Gulf of California has received the drainage of the range for an incalculable period, and its results are stupendous. For 500 miles the river winds through a gorge, termed the Great Cañon, whose sides rise from 3000 feet to 6000 feet above the bed of the river to the plain, in a succession of terraces having perpendicular walls ranging up to 1000 feet in height. From both sides of the main gorge numerous smaller cañons enter, intersecting the whole plain, and deepening as they approach the main trunk. This river has cut through the TERTIARY and SECONDARY formations, down even to the Carboniferous limestones of the PRIMARY, and millions of fossils, washed out of the rocks, lie scattered about. When this singular region first became known, it could not be credited that flowing water had carved out the surface to such an enormous depth; but the careful labours of the United States Geological Survey leave no doubt whatever that

water has been the only agent in the production of this unparalleled example of denudation and erosion.

We have one good historical instance of the rate of wear and tear in the case of the river Simeto, which was dammed by a stream of lava from Mount Etna at the beginning of the seventeenth century; but in the course of 225 years, when examined by Sir C. Lyell, it had cut itself a channel through this hard barrier, ranging from fifty to several hundred feet wide, and from forty to sixty feet deep. Uncertain as this may be as a guide in estimating the time occupied by the Colorado in cutting its channel, it is at least suggestive of a very prolonged period. Some idea of the mass of material removed by a river during a single year may be gathered from calculations which have been made with extreme care and may be accepted as trustworthy. Thus, the fine mud alone brought down annually by the Mississippi to the Gulf of Mexico would form an accumulation 260 feet thick and a mile square—omitting the heavier material; and the Rhone carries in suspension sufficient carbonate of lime to cover an area of two square miles a foot in depth. The terraces often observable along river valleys well exemplify the eroding power of the stream, which, as it deepens its channel, leaves a series of flats to mark its level from time to time. In sandstone and limestone formations, caves are frequently hollowed out in the banks, and as the water level falls they become inaccessible to floods. These are often situated very far above the present level of a river, but their floors bear evidence of having been originally within its range by the

presence of silt and mud, with shells, fish bones, and other remnants of aquatic life.

Professor S. Haughton has made some interesting calculations of the time required to remove one foot of earth from the whole of the rain basins of certain rivers, and finds the mean to be about 3000 years. The following is his table :—

	Years.
Ganges	2358
Mississippi	6000
Hoang-Ho	1464
Yang-tse-Kiang	2700
Rhone	1528
Danube	6846
Po	729

Carrying his speculations further on this basis, and allowing the formation of strata to have gone on at ten times the present rate, he arrives at the conclusion that the whole of geological time is represented by a minimum period of 200,000,000 years.

"Faults" are frequently enlarged by denudation to a very great extent, until a wide interval is left between the two edges of the broken stratum, which again is filled with a "dyke" of fresh material. In this manner vast quantities of a rock have been removed, leaving the two cliffs of the originally dislocated formation far apart, and enclosing a bed of sand, clay, gravel, or other accumulation in the gap—the result of water action in some one of its forms.

Not only on the surface, but deep in the earth are hills and valleys, though the former do not exist as elevations, nor the latter as depressions, their contours

being masked by overlying rocks or sands. Remove these latter, however, and the old lines of cliff and shore, highland and lowland, lake and river, may in some instances be clearly traced. In other cases the sites of ancient lakes, sea-beaches, volcanic craters, lava streams, etc., may be made out, with forests and swamps and every other disposition of land with which we are familiar in daily experience. The proportions of land and water, the courses of rivers, and the shapes of continents have altered vastly in geological time; but the leading physical features of a period are sometimes firmly impressed upon its rocks, in which we have a mirror, broken, it is true, but still capable of reflecting, in its shattered fragments, many a landscape on which once shone the light of day.

Short as it is, the historical period affords abundant examples of both slow and sudden changes of level. In the year 1819 a remarkable depression took place in Cutch, in Hindustan, extending over 2000 square miles, converting this large area into a lagoon during the rains; and in the same year great activity was noticed in the Central American volcanic range, in which the crater of Jorullo occupies a conspicuous place. Even so recently as 1845 a minor subsidence occurred. The group of islands in the Greek Archipelago, which includes Santorin and Theresia, has received several additions since 186 B.C., and islands have appeared among the Aleutian group, the Philippines, Moluccas, Azores, etc., within the past century, and have become permanent additions to the land surface. In 1855 the ground of the

town of Wellington, New Zealand, rose two feet, and other places in the island much higher. The Chilian earthquake of 1822 elevated the shore-line several feet for a distance of a hundred miles, and emptied water-courses inland. The result, however, is not always permanent, for islands have frequently disappeared, and raised surfaces returned to their original level within a short time. The bed of the ocean is also the scene of disturbances of a volcanic character, similar to those which periodically affect the land. During the last twelve years the western coast of South America has been devastated several times by violent incursions of the sea, erroneously termed "tidal" waves, though they have no relation whatever to tidal action. The sea suddenly rises, and a wave or wall of water, twenty or thirty feet high, sweeps along the coast with irresistible force, swamping ships at their anchors or driving them ashore, and wrecking every building within reach of its influence. This is sometimes preceded by an equally sudden fall of the water, followed immediately by the "earthquake wave," as it undoubtedly is, with widespread destruction and loss of life. During a similar influx of the sea on the Island of St. Thomas, some ten years ago, a vessel of the United States navy was torn from her anchor, carried a long way inland, and left high and dry, with palm trees growing between her and the sea.

Sudden depressions and elevations of a considerable submarine area would have the effect of communicating a strong wave-like motion to the sea in the vicinity, and the frequently observed undulations of the land itself

during earthquakes confirm the belief that these catastrophes are due to the impulse so communicated. In some instances, earthquake waves arising at the foot of the Andes have apparently been propagated to islands far out in the Pacific, indicating the wide range of the propulsive force.

The network of telegraphic wires extending all over the world does good service in enabling accurate comparisons to be made of the times of occurrence of disturbances, and the sympathy between far distant volcanic regions has been ascertained by repeated observations. Some very interesting evidence has been collected by deep-sea exploring expeditions on the volcanic nature of the deposits on the floor of the ocean. Lava, volcanic ashes, etc., have been dredged up far from any active volcano—the most probable inference in these cases being that they have been ejected from submarine craters. Pumice-stone has also been met with by ships in almost incredible quantities, covering the sea for miles so thickly that the vessel has had difficulty in making way through it. In examining one of the charts of the sea bottom constructed by the scientific staff of the *Challenger*, one cannot fail to be impressed with the similarity to that of a mountainous land surface. Here are ridges of great elevation, sometimes serrated, sometimes rounded; valleys of great depth, abrupt precipices, gentle slopes, and circular crests of rock, sloping very gradually in some directions and going sheer down in others, and suggesting the crater form. The main lines of configuration are thus shown to be so similar to those prevailing

on land, that we cannot hesitate to ascribe to them the same origin. In confirmation of this, the statement of the captain of a British ship, as recorded in his log on January 29, 1878, is important, though it is only one of many similar observations. When in lat. 4° 20′ N., long. 21° 45′ W., several submarine volcanoes were seen throwing large columns of water a hundred feet into the air, the sea being in a state of great commotion, and a sound like distant thunder being audible. Two days before this date a destructive earthquake wave had visited Callao and other towns on the South American coast.

In the present state of our knowledge, or rather ignorance, little is to be gained by discussion on the probable cause of volcanic action. What sets up this action? It may be the sudden cracking of rocks under immense strain from subsidence—as when ice on a lake, the water level of which is falling, cracks in settling down, with a loud report and a movement quite perceptible to any one standing still upon it. The view at one time entertained, viz., that masses of molten matter beneath the surface were somehow set in motion, surging like waves against the more solid upper crust, is not so generally held as formerly. The generation of steam, and even its sudden condensation, may possibly be among the causes of the various exhibitions of volcanic energy which cannot be satisfactorily explained in the absence of any direct evidence. It is manifest that quantities of water do reach the underlying strata through fissures in the surface rocks, and become con-

verted into steam of high pressure; as in the Great Geyser of Iceland, which sends up a column of boiling water 150 feet high, and ejects steam with prodigious violence. In the reservoir at the base of the outlet pipe of this hot spring, the steam gradually collects until its pressure on the surface of the water forces out a jet, and, the strain being relieved, this subsides, the steam rushes out after it, and periods of quiescence follow the eruption at irregular intervals. Where steam is generated and can find no regular means of escape, it is likely to set up a movement of the earth similar to that experienced during earthquakes; and the probability that the access of water to the heated lower strata is concerned in these phenomena is strengthened by the fact that all the active volcanoes of the world are situated near the sea.

Taking a general survey of those regions of the earth subject at the present day to more or less intense volcanic disturbance, we find they bear a considerable proportion to the whole land surface, and isolated centres of activity, such as the Azores, Canaries, Verds, and Iceland, in the Atlantic, and the Society, Galapagos, Marquesas, Friendly, Philippine, and other islands, in the Pacific, indicate points of small resistance to the internal force even in the great oceans. The whole western coast of America, and the region on a line drawn from Spain along the Mediterranean, through the north of Persia and the Himalayas, south-eastwards through Sumatra and Java, and again north-east through the Moluccas, Philippines, Formosa, and Japan, to Kamt-

chatka, are scenes of periodical or permanent disturbance. In so small a region as that of the Philippines, no less than forty-one earthquakes were recorded in 1876; and if the whole of such occurrences were registered, they would probably amount to hundreds yearly in North and South America. The total amount of contemporary volcanic action must then be effecting important geological changes.

Not less well-defined than the above, but far more regular and tranquil, are the elevations and depressions to be observed on coast-lines. The greater part of the Pacific coast of South America is being slowly elevated, as also the shores of Japan, North Greenland, Siberia, Spitzbergen, the Scandinavian peninsula, the Mediterranean, etc. In Scandinavia, the rise is about three or four feet in a century, and within the Arctic circle it has probably been more rapid; for the remains of shells and fishes, identical with those still living in the adjacent seas, are found at a height of 150 feet, or more, above the present shores. Elevation has been stated to affect even the pine forests in those parts of Norway which are being elevated—the trees on the greater heights dying as they are lifted into an atmosphere too cold for them.

Subsidences, corresponding to these elevations, are equally numerous. Thus, South Greenland, parts of the coast of India, the Atlantic shore of North America, and oceanic islands in various parts of the world are areas of depression. In England, we have the celebrated forest bed of Cromer, on the Norfolk

coast, which has been sinking, at least comparatively recently; for the stumps of trees, in the position in which they grew, are found below low-water mark, and logs of wood and bones of extinct terrestrial animals have been dredged up some distance at sea. This forest can be traced with the greatest certainty from the cliffs to the bed of the sea, and others equally so on the coasts of Devonshire and Cornwall, about Falmouth, Dartmouth, and Torbay. The Norfolk coast is probably quite 500 feet, and the Cornwall 60 feet below the level they occupied while these forests were growing, according to estimates made on the spot, and after consideration of all the circumstances, by Sir Charles Lyell and Mr. William Pengelly. Tree trunks and other vestiges of forest-land occur round the shores of Jersey and Guernsey; and if old histories and charts of these islands are trustworthy, it would appear that before the fifteenth century this tract was at least 150 feet above the sea level. At the southern extremity of Sweden, in the district of Christianstad, streets in the coast towns have sunk below the level of the sea, and the high-water mark is more than thirty yards nearer inland than it was 150 years ago. On the other hand, in the northern fords of Norway, the old beaches are raised several hundred feet above the sea; so that Scandinavia is subject to irregular movements of upheaval and depression. In one direction, the peninsula is gaining land by elevation of its shores and sea-beds above tidal influence; and in another, losing by their depression and the consequent encroachment of

the sea upon lands which were formerly above its reach. Similarly, terraces have been formed in the neighbourhood of Leith and Greenock of very unmistakable character.

In all these cases, the question might arise whether the observed changes in the relative positions of sea and land were not due to a change in the level of the former rather than of the latter, if we had not conclusive evidence on the subject. In the first place, if the level of the sea is lowered at one place, it must also fall uniformly at others, and *vice versâ;* as we know by an invariable law of the motion of fluids. The appearances created by such a rise or fall must also be uniform. If we have a water-formed terrace on one part of a coast, another, of corresponding height and parallel with the water-line, must continue the whole length of the coast, on the supposition that the water has fallen; and if it has risen, we must have a uniform measure of submergence. But what are the facts? Leith is built upon a marine terrace, while further south we find the Cromer forest, with its trees, submerged. How did the shells and water-worn stones of the Leith terrace come to be many feet above the level of the sea (having once been below it), and the forest of Cromer to be far below it (having once been high up on the shore)? These two contradictory appearances cannot be accounted for by any fall in the sea; but easily by an irregular movement of the land. Direct proof that the movement is that of the land and not of the sea, is obtained in another way

from the terraces themselves. They are often much higher—twenty or thirty feet—at one point than at another not very far distant on the same coast. On the hypothesis that the sea has fallen, the line of the terrace should be practically horizontal—with, perhaps, slight irregularities, but nothing like so great a discrepancy. We find it, however, twenty feet or so higher at the end of one half-mile than at the other, and can perfectly understand this condition of things if we ascribe it to an elevating force in operation far below the level of both sea and land. One more argument may be added to the above. The Arctic Expedition under Sir G. Nares found, at a height of 1000 feet above the sea, at the head of Robeson Channel, in about lat. 82° N., marine shells and plants, specifically identical with those now living close at hand in the Arctic seas. Unless they were placed there by the elevation of the land, the sea must have sunk 1000 feet; and such a prodigious fall would enable us to walk across all the channels round our coast, and a long way out into the Atlantic Ocean. In fact, the loss of 1000 feet of the depth of the sea would effect an astounding alteration over the whole of the globe; and such a quantity of water could by no means have escaped from our atmosphere by evaporation, and have become lost to us for ever. The fall of 1000 vertical feet of water over the whole ocean surface might possibly be provided for by an extreme depression in the beds of the great oceans; but in that case we should have abundant proofs of this great catastrophe.

The movement under consideration has taken place comparatively recently, and the proof that it has not been universal, but simply local, lies in the fact that adjacent countries show a quite recent encroachment of the sea, when they should show a recession if so vast a fall in the water level near them had taken place.

Other general evidence of these gradual but powerful up and down movements of the earth's surface may be pointed out in all geological ages, from the Laurentian to the present era. Were no remains of plants and animals included in the strata far down in the depths of the earth, as well as high up in the solid rock of our mountains, we might conjecture, but could not positively assert, that such immense changes of level had occurred. Not fifty years ago certain explanations were given and accepted by otherwise intelligent and educated people, which failed altogether to meet the case in reality, but were sufficient for the day, or, at least, considered sufficient. They passed current, for few had the knowledge requisite to enable them to examine into them; and much prejudice, besides, existed against the calm survey of facts, which were certainly startling, and therefore received with positive incredulity. It was known to the ancients that the distinct and unmistakable forms of marine animals were to be found below the surface in quarries, and above the level of the sea on mountains. Aristotle and Strabo speculated with admirable judgment on these facts, and touched the true explanation of them; but since university education, even so late as the last generation, ignored physical science, the general body of

the best-cultivated class in the country was actually behind the time of Strabo in appreciation of these striking phenomena. Happily, both the ignorance and prejudice are fast receding before the irresistible pressure of more complete and liberal culture.

Animals and plants, it is obvious, must live either on land or in water, and to most of us the characteristic forms of both are well known. We should recognize them anywhere without hesitation, so long as their shapes were fairly well preserved. We have watched the whole process, it may be supposed, of sinking a shaft 1000 feet deep for coal; and all through the strata we have seen the bones of fishes and land animals, shells, and plants, in various conditions of perfection, but always easily identified as such. These must inevitably have occupied land and water at one time. Yet we find them here! Or we are exploring a fissure in the rock of a limestone mountain now 1000 feet above the sea level. Frost and rain have cracked off portions of the rock, and among the rubbish we again find shells and bones, with similar evidences of marine life. It is contrary to all our experience and knowledge to suppose that these once living creatures could have passed their existence in the heart of that rock in its present position, and away from their native element—in the one case 1000 feet below it, and in the other the same distance above it. Reason convinces us that we are not looking at mere counterfeits of the familiar forms, and we feel that it would be more difficult to account in any supernatural way for so perfect a resemblance than to accept

it as a reality—a true and actual presentment of an animal once rejoicing in life. The testimony of the senses, corroborated by the faculty of comparison, excludes the idea that we are contemplating an accident, and suggests a law of nature whose operation can and should be intelligently studied.

The principles of upheaval, subsidence, and denudation enunciated in the foregoing pages will carry the reader through succeeding chapters. Later geological times have witnessed the effect of a potent agent in denudation—ice—which has impressed so marked a character upon the superficial contours of the now temperate portion of the Northern hemisphere.

CHAPTER V.

THE ORGANICALLY FORMED ROCKS.

The Laurentian series, with eozoön and early vegetable forms—The coral limestone series—Chalk; its formation at the present time in the Atlantic and Pacific Oceans—The Carboniferous period; formation of coal, lignite, etc.—Arctic coal—Climate of the period—Magnitude of the coal measures—Physical and chemical origin of coal; influence upon it of heat and pressure—The nummulitic limestones and their recent origin.

Many of the stratified rocks possess a composition which distinguishes them from others of the same class, and wholly separates them from the unstratified series. They contain so large a quantity of organic matter, derived from animal or vegetable life, that they may truly be said to be "organically formed." Chemical and mechanical action has greatly modified the original life forms; but these rocks still retain indubitable evidence of their origin. As phosphate and carbonate of lime are among the principal constituents of the hard parts (bones and shells) of animals, so carbon is an important constituent of plants. After the death of the plant or animal, these form a solid residuum, collected

by the living organism, and left, on its dissolution, to testify to the source whence they were derived. It may be necessary, however, to remark that, whereas animals derive their phosphates and carbonates of lime from the water in which they live or the food upon which they subsist, plants obtain their carbon from the atmosphere—to a large extent, if not chiefly—through their peculiar power of decomposing it in solar light. In either case the process is one of assimilation—the plant or animal gathering to itself that which is necessary for building up its framework and giving it strength and rigidity.

Among organically formed rocks may be included several of the limestones, as chalk and coralline limestone—derived mainly from the bodies of marine animals; and coal, lignite, peat, etc.—the remains of decayed vegetation, influenced, in many instances, by heat and pressure. They are of all ages, from the Laurentian to the present time. Wherever life has existed, these rocks have accumulated, and their immense thickness and extent indicate the exuberance of that life or the length of time during which it existed.

We may regard it as at least probable—the evidence all tending to this conclusion—that vegetable preceded animal life upon the earth, or at least that the lowest forms of both were contemporaneous, while we are quite certain that the higher aquatic and terrestrial forms did not come into being until vegetable life had attained an extraordinary development, and had, so to speak, held dominion of the land for long ages. We have seen how

sandstones, slates, clays, and limestones are formed by the disintegration of other rocks. The three former are entirely sedimentary, and never exhibit an organic character, though they are often crowded with isolated animal remains, imbedded as in a matrix or mould; while the latter is also generally sedimentary, and usually to a great extent organic throughout. A limestone may nevertheless be composed entirely of free material once held in suspension in water, and in that case is not, strictly speaking, an organic rock; and small deposits occur which have a purely chemical origin. In whatever form a limestone rock may appear, and though all direct trace of its origin should have become obliterated, animal life has most probably been concerned in gathering together its calcareous particles at some period of its history.

The larger animals have contributed nothing of importance to the accumulation of these astonishing deposits of limestones; they are chiefly the work of minute and microscopic organisms—marine shell-fish, corals, foraminifera, madrepora, and encrinites (sea-lilies)—existing in countless millions, and building for countless ages from the calcareous and silicious matter washed out of the land and held in solution in the water, whence it is drawn by them to maintain the economy of life, and eventually deposited in an ever-increasing mass, until it attains a thickness of several hundreds of feet.

So far back as Laurentian times (see table, page 51) we find one limestone-builder, a marine foraminifer (Latin, *foramen*, an opening, *fero*, I bear) called *Eozoön*

(Greek, *ēōs*, down, *zoōn*, an animal), probably one of the earliest—at all events the oldest with which we are acquainted—of living creatures entitled to rank as an animal, distributed in quantities throughout these rocks, which, it can hardly be doubted, they contributed to form. Masses of carbon, in the shape of graphite, occur too, which may well be changed vegetable matter; besides other indications that the earth was not even then destitute of life.

In tropical seas, we have daily opportunities of observing the growth of coral reefs and barriers; and, comparing these with the old coralline limestones, we recognize in them essentially identical characteristics, such as are to be found in the coral rag of the Middle Oolite in Wiltshire. It is only necessary to glance at the large area occupied by the coral formations of the present time—in the Pacific Ocean, along the north-east coast of Australia, and thence into the Chinese and Japanese seas—to assure ourselves of the extent of work done by these small creatures. One such reef extends for at least 700 miles in the Pacific, another nearly 400 miles, and there are several more of less dimensions. All this material is derived by the animals from the carbonate of lime contained in the water of the ocean, and cemented together by their vital functions. As early as the Silurian era, and all through the Devonian, corals abounded and formed masses of limestone, and so on with few interruptions down to our own time. The species vary, but the type is persistent, the materials used and the work accomplished essentially the same.

The Cretaceous age has been so named from the preponderance of chalk or carbonate of lime in the formation. This is emphatically an organic rock, as we know, firstly from microscopic examination of its particles, and secondly from the direct testimony afforded by deep dredgings on the floor of the ocean. This subject has been referred to previously, in order to show that chalk is a stratified rock; it remains now to prove its organic origin.

Professor Sir C. Wyville Thomson, the chief of the scientific staff of the *Challenger* expedition, gave a description of the process of chalk formation at the meeting of the British Association in September, 1876, which is so admirably clear and concise, that it will be best to give it in its entirety.

"Many years ago it was determined by observation, even previous to the soundings for the first Atlantic cable, that over a great part of the North Atlantic a very remarkable deposit was being laid down—a deposit now known as 'globigerina ooze.' This deposit consists of the shells of minute foraminifera, principally belonging to one genus—the genus *Globigerina*. This, as we found it in these deposits, was a small-chambered shell extremely minute, about a millimetre in diameter; and these shells were found in enormous quantity. When dry, the ooze was something like fine sago, with little, round shells falling from one another, and showing that the deposit was formed almost entirely of such shells. Some other genera were mixed with them, but the great mass were

globigerinæ. When we took up by any means material a little below the surface of sea bottom, we found the globigerina shells were becoming broken and compacted together, so as to form a close and nearly amorphous (without definite form) mud, in which there were very many complete globigerinæ and many pieces of the same. The whole of this deposit was composed almost entirely of carbonate of lime, and the only rock which this could possibly form was a limestone. It therefore appeared that over a very large portion of the North Atlantic, and over many other parts of the world where these observations had been made, this limestone was being laid down. Further observations showed that the chalk was composed of very nearly the same material, and the analogy between these modern formations and the chalk became very apparent. During the voyage we had many opportunities of bringing up this modern chalk." He then discusses the question whether these little creatures live upon the surface or the bottom; but Dr. W. B. Carpenter and others have come to the conclusion that they exist in varying proportions at all depths, especially on the surface in the Mediterranean, and have even been brought alive from the sea bottom, where Dr. Carpenter believes that they breed. Sir C. W. Thomson proceeds. "The tow-net upon the surface, and particularly at a little below the surface—that is to say, to the depths of a few fathoms, or even to a hundred fathoms—takes enormous numbers of these foraminifera which make up the globigerina ooze, alive. . . . When we find these shells at the bottom, they are little globules

all united together, and forming a little compound mass of globules. These are rough on the surface, and perforated with minute pores. When the globigerina was found on the surface, the shell was of the same form; but instead of being white and opaque, it was perfectly clear and transparent. A raised frill on the shell forms a hexagon round each minute pore, and runs into six points, and from each point a long spine projects; in fact, the shell bristles with long spines running out in every direction, the axes of the spines on each chamber meeting in the centre of the chamber. The shell has a little animal in the interior of it, and that animal consists of a particle of gelatinous matter like the white of egg; and, when alive, this matter runs out of the holes on the surface of the shell to the end of each of the spines, while it absorbs minute particles of organic matter floating in the water. The globigerinæ seem to be of the same specific gravity as the water, their weight being reduced by large oil globules scattered in quantity through their substance. They exist in myriads on the surface, while they are perpetually dying and sinking to the bottom."

Here then is, so far as we know it, the life-history of the chalk-builders, and there can be little doubt that similar organisms have had a very large share in the work of gathering up from water its dissolved particles of lime and silica, and forming them into shells, which, after decay, appear as a fine ooze or mud; and this, under the pressure of superincumbent strata deposited above it subsequently, and in virtue of

the cementing nature of the material itself, eventually became a limestone rock. The shelly marbles betray their origin at once by their texture, for they are simply an aggregation of fragments of marine shells, while such qualities as are used for sculpture, and sparkle with minute crystals, are of probably the same class but metamorphosed by heat. Again, the encrinital or

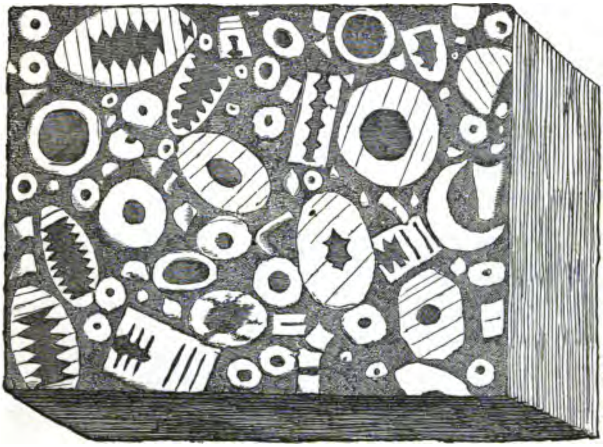

FIG. 6.—Section of Crinoidal limestone, showing the stems, etc., of the Crinoids intersected as they lie in different positions in the stone (Carboniferous).

crinoidal marbles of the Upper Primary strata are so loaded with fragments of extinct zoophytes (plant-like animals), that they may be said to be entirely composed of their remains.

Mr. H. C. Sorby, President of the Geological Society in 1879, gave, in his Anniversary address, the following table of the origin of limestones.

Name of rocks.	Chief constituent fragment, etc., in descending order.
Cretaceous	Shell prisms, Foraminifera, Coccoliths.
Wealden	Freshwater aragonite mollusca, Entomostraca.
Jurassic	Chemical deposits, Aragonite mollusca and corals, Brachiopoda, Echinoderms, Shell prisms.
Permian	Original structure lost by dolomitization.*
Carboniferous ...	Encrinites, Brachiopoda, Foraminifera, Corals, and Polyozoa.
Devonian	Encrinites, Corals, and allied organisms.
Silurian	Encrinites, Corals and Polyzoa, Brachiopoda, Trilobites.
Metamorphic ...	Original structure lost, Quartz and Silicates formed *in situ*.

Though this difference must to a great extent have depended on the nature of the organisms living at each period, yet it must also have depended on the accompanying mechanical and chemical conditions of the water in which the deposits were formed. The structure of each rock was therefore dependent on two most important circumstances, and we need not be surprised to find the results so varied and characteristic.

The organic rocks hitherto described are those of animal origin; another great group owes its existence to vegetation. Towards the upper part of the PRIMARY or PALÆOZOIC, above the Devonian and below the New Red Sandstone (see table, page 51), is the Carboniferous (carbon-bearing) group, whose lower strata are limestones, shales, sandstones, clays, grits, ironstones, etc., the upper being coal-beds, as roughly classified. These are frequently interstratified—a bed of coal lying between two or more of limestone, and a limestone between two beds of coal. The Carboniferous

* *i.e.* a change effected by crystallization.

system is found, with coal at accessible depths, from near the surface to 1000 feet and more below it, in all the great divisions of the globe, and in most localities where the SECONDARY and TERTIARY formations have been partially removed by denudation, or the PRIMARY have been upheaved among them. It is not improbable that coal was formed in the Silurian era, though there is little direct evidence of this; but it is fairly abundant in the Devonian. Later, too, than the true Carboniferous, the Jurassic, Cretaceous, and even some of the TERTIARY formations contain coal; but never in such abundance nor so uniformly distributed as in the upper division of the PRIMARY—the seat of the true coal measures.

This period has always been considered a very remarkable one in geological history. It is specially an age of vegetable growths, belonging exclusively, however, to the lower forms of plant life—forms which at that time attained colossal proportions, but are now represented by insignificant congeners, occupying a very unimportant position, and contributing little to the vegetable accumulations of the present. At least so far as the Northern hemisphere is concerned, it is probable that the climate of the coal period was of a very uniform character, since we find almost an identity of species in plants from the coal measures in North America, Central and Northern Europe, and other widely separated regions. Whatever the physical conditions of the time were, they have never prevailed before or since in so marked a manner. It has been suggested that the atmosphere was much more

highly charged with carbonic acid than now, to afford the materials for so astonishingly luxuriant a vegetation as must have flourished to provide the immense stores of mineralized vegetable matter contained in these deposits. Chemically speaking, coal is carbon (mixed with a certain amount of foreign mineral matter) accumulated by plants growing in the light of day. A piece selected at random from that used for domestic purposes will seldom afford any visible clue to its origin; but at the base of a coal seam we frequently find the stems of the plants in the upright position of growth, with their rootlets penetrating the shale (formerly mud) below. Moreover, these shales contain masses of the stems, leaves, bark, seed vessels, etc., in a beautiful state of preservation and in countless multitudes. Hugh Miller thus describes a colliery near Wolverhampton:—

"It presents the appearance of a moor on which a full-grown fir wood had been cut down a few months before, the stumps only being left behind. Stump rises beside stump, to the number of seventy-three in all; the thickly clinging roots strike out in every direction into what seems once to have been vegetable mould, but exists as an indurated, brownish-coloured shale. Many trunks, sorely flattened, lie recumbent on the coal; several are fully thirty feet in length, while some of the larger stumps measure rather more than two feet in diameter. There lie thick around stigmariæ, lepidodendra, calamites, and fragments of ulodendra; and yet, with all the assistance these lent, the seam of coal formed by this ancient forest does not

exceed five inches in thickness. Not a few of the stumps in this area are evidently water-worn. The prostrate forest had been submerged, and mollusks lived, and fishes swam over it. This upper forest is underlaid by a second, and even a third; we find three full-grown forests closely packed up in a depth of not more than twelve feet."

None of our hard-wood trees—oak, elm, ash, etc.—have yet been discovered in the coal measures; the vegetation was altogether of a more simple character, and flourished in marshy situations, along low-lying shores and islands, and upon muddy flats, within the influence, it seems in some cases, of the tide and frequent inundations. The majority of these plants were flowerless, but some were conifers, allied to existing pine trees. The principal groups of plants were lepidodendra, represented by our club-mosses; calamites, by our horse-tails; sigillaria, by the cycads or false palms; ferns in wonderful variety and abundance; and the pine-like conifers. A living coal forest must have presented an exquisitely beautiful appearance. Its trees, though of a low botanical order, were gigantic of their kind, and furnished with a delicate feathery foliage, forming a dense canopy, through which the direct rays of the sun could seldom penetrate to the earth; while the ground was covered by a thick carpet of ferns and mosses. The traveller—had there been any to look upon the beauty of these forests—passing from island to island, and from continent to continent, would have noticed that they had a uniform height of not more than fifty or sixty feet; that the

brilliant green foliage glittered in the sunlight; but few insects were to be seen in the air; and not one solitary call of a bird could be heard in the universal stillness, nor the flash of a wing, small even as that of a humming-bird, to give life to the scenery. Around him the waters swarmed with fishes of predaceous habits, allied to the sharks and pikes; and if he had entered one of the forests, he would have encountered scorpions, spiders, and centipedes, and various uncouth amphibians crawling over the damp earth.

The forces of depression and upheaval were in active operation during the whole of this period, and the Carboniferous area was in the main one of subsidence. The great depth at which some of the deposits are now situated indicates the extent of the subsidence; for this was a terrestrial vegetation, wholly dependent for its existence on light and air. Numerous seams in the same coal-field show that forest after forest must have flourished and decayed age after age on the same spot, the land being alternately submerged and elevated at longer or shorter intervals. In one place, we have a bed of coal overlaid by sandstone, formed in an estuary, containing the remains of aquatic animals; and again a layer of coal with a lacustrine limestone above that. In another, the stems of the plants stand erect, with their roots in the shale or clay on which they grew, and penetrate above far into a band of limestone, showing that when the plants stood submerged on the floor of a fresh-water lake, its limestone sediment was deposited around and above them. The presence of alternate beds

of terrestrial vegetation and water-formed rocks cannot possibly be accounted for on any other supposition than that the locality where they occur was exposed successively to air for a given period, to water for a second, and again brought to the light to sustain another forest. Instances occur where the roots of the plants strike direct into a seam of coal in the exact position in which they grew upon that coal when it was a mere mass of decaying vegetation; and the microscope tells the same story, revealing, in many samples of coal, the fragmentary structure of woody material.

Some limited beds of coal have, no doubt, been formed from accumulations of floating timber, such as collect after floods in many of the great rivers of the world. Living and dead trees and branches are swept by the water from the forest slopes into the stream, where they collect in extensive rafts, travel perhaps hundreds of miles, become water-logged and stranded in some quiet spot, and eventually covered with river sediment. In time, this mass will obviously become coal in some form. Similarly, cypress swamps, mangrove jungles, and other estuarine vegetation of large tropical river basins may be conceived to contribute deposits like lignite or brown coal, which only need time, the pressure of superincumbent strata, and heat to become converted into true black coal. In a minor degree, peat-mosses, which in some countries cover hundreds of square miles and have a considerable depth, and vegetable drifts from all land surfaces, help us to comprehend the means by which coal may be formed at all times.

Far later than the Carboniferous period, and derived from plants of a higher organization, are the fossil resins and gums, of which amber is an example. Its vegetable origin is hardly doubtful, for it frequently contains fragments of leaves and insects, and, after burning, yields a residuum of carbon, and is found associated with fossilized wood.

The climate of the Carboniferous period was probably semi-tropical, if we may judge from the character of some of its plants, whose representatives are now restricted to warm regions, and from the fact that species of corals which do not now belong to cold regions abounded in the seas of the time in Northern Europe. But this need not astonish us, for there are many convincing proofs that the zones of temperature have been subject to much secular variation. Thus, in the middle of the TERTIARY era, a tropical jungle, infested by crocodiles, covered Hampshire; and far north of ice-capped Greenland, within 500 miles of the North Pole, the climate was temperate enough to admit of the growth of a forest, whose decay has produced a fairly thick seam of good coal.

As one factor in the surface temperature of the earth, we cannot but attribute considerable influence to the heat constantly radiating from it into the surrounding atmosphere. At irregular periods of our planet's history, the heat so radiated has probably been much in excess of the average. It is not difficult to conceive that, during one of these periods of excess, the water of the ocean partook of the general rise in temperature, and

the earth became shrouded in a pall of warm vapour precisely adapted to the luxuriant plant life which flourished in Carboniferous times. Under such conditions, there would be no frost, and little direct sunlight to wither vegetation. Variability in the amount of heat transmitted from the sun would also produce a corresponding effect upon our surface temperature, and explain both the warm and cold periods of Northern Europe. Modern astronomy goes very far indeed towards establishing the probability of considerable variations in the solar heat—sufficient to bring about great modifications in terrestrial climates.

During their long descent to the depth at which we usually find them, it was inevitable that the vegetable remains of the coal forests should have been subjected to pressure in every direction; but especially from the deposits forming above them. The pressure alone would be sufficient to generate considerable heat, but they have also come into direct contact with highly heated rocks, which have in some instances been squirted along the seams, reducing the coal to a mass of soot. Heat, compression, and chemical action, then, have changed the originally beautiful forms of sigillaria, lepidodendron, calamite, cycad, and fern into a black, crystalline rock, with few indications to the naked eye of its origin and history.

Distinct from the true Carboniferous coals are the workable beds among the Devonian, Jurassic, Cretaceous, and Middle TERTIARY rocks; but the history of all is similar, though, as will be seen subsequently, the

marine and terrestrial animals were widely different. Little, comparatively, is known of the land surface of any period up to the Carboniferous, or of its terrestrial fauna (animals) or flora (plants); and even through the Triassic and Jurassic, abounding as they do with reptilian types, the true air-breathing creatures are limited to a few singular forms. The beginning of the TERTIARY era ushered in a new phase of life, characterized by the higher orders of animals and plants, which have handed down more or less modified representatives to our own times. The beginning of the Carboniferous age enables us to draw almost a sharp line between our ignorance of the land before, and our knowledge of it during and after this period. We then first obtain a clear perception of a vastly extended series of continents and islands clothed with rich vegetation. It is not contended that such conditions may not have obtained much earlier, for denudation may have removed the evidences though they existed; but indubitable proofs of the physical state of the earth are preserved for us in the coal formations, whatever approach to like conditions might have been attained during former ages.

It is unnecessary to dwell upon the economic value of coal, which has been a most powerful agent in human civilization, especially since its application to the reduction of the metals and the generation of steam. Associated with it in the same formation, iron is usually found, and the two minerals combine in promoting human welfare and multiplying our available strength

a thousandfold. Great Britain, Belgium, and North America possess some of the most valuable coal measures yet known, and the annual yield from these three sources alone must be enormous. Dr. Siemens has calculated that by the end of this century we shall require a yearly supply of 250,000,000 tons, basing his estimate on the report of a Royal Commission, which stated the production from the mines of Great Britain to be 123,000,000 tons in the year 1872, which had risen to more than 134,179,000 tons in 1877. Extending these figures to the coal-fields of the whole earth, we have a faint conception of the vast accumulations they represent, due to the decomposition of atmospheric air by plant life.

When George Stephenson was asked what was the ultimate cause of motion in his locomotive engine, he replied, in graphic, but not strictly philosophical terms, "that it went by the bottled-up rays of the sun." Coal is, no doubt, the product of solar energy acting upon the surface of our earth, and Dr. Siemens has thus aptly described the physical and chemical process. "The rays of the sun represent energy in the form of heat and light, which is communicated to our earth through the medium which must necessarily fill the space between us and our great luminary. If these rays fall upon the growing plant, their effect disappears from direct recognition by our senses, inasmuch as the leaf does not become heated, as it would if it were made of iron or dead wood; but we find a chemical result accomplished, viz., carbonic acid gas, which has been

absorbed by the leaf of the tree from the atmosphere, is there dissociated, or separated into its elements, carbon and oxygen—the oxygen being returned to the atmosphere, and the carbon retained to form the solid substance of the tree."

Whatever, then, the measure of solar energy conveyed to the plant in the formation of one pound of carbon, as represented by wood fibre, that energy will reappear when the coal is heated sufficiently to enable its carbon to combine with the oxygen of the air, and restore to it the carbonic acid originally abstracted. The plant, during its life, actually breaks up the connection between the oxygen and carbon contained in the carbonic acid, restoring the former to the air and appropriating the latter to itself. Under the influence of fire this process is merely reversed—oxygen being taken from the air to combine with the carbon of the plant, which is then "consumed," as we say, but has, in fact, been reconverted into its original constituents, leaving behind nothing but a small quantity of mineral ash—generally lime, silica, and iron—taken up by the plant tissues mainly from the soil.

When chemically analyzed, coal is found wanting in some of the constituents of wood fibre; but this does not invalidate the conclusion, founded on other strong evidence, that it is derived in the first instance from vegetation; and, as in the case of other rocks, we cannot trace all the influences which have been brought to bear upon it, nor expect to be able to reconstruct the original plants in their entirety. Sufficient, however,

remains, both in the plant forms actually preserved, and in the more or less pure carbon invariably present in true coal, to banish all doubt of its organic origin.

In the limestones of the Carboniferous system, the carbon is in combination with oxygen and lime, and these rocks are mainly of animal origin; while in the coal itself the carbon greatly predominates.

The lower orders of the animal and vegetable kingdoms have been chiefly concerned in building up the vast masses of rock constituting the organic series—in the aggregate tens of thousands of feet thick; while the giants of the earth, the highly organized animals and plants, have done comparatively little. We have seen what coral animals and minute foraminifera can do; not less stupendous is the work of another foraminifer, the *Nummulite*, also an inhabitant of the sea. The shell is in shape similar to a coin (whence the name, Latin, *nummus*), and about the size of a farthing, divided internally into numerous chambers. The general appearance of a nummulitic limestone is that of a mass of coins lying in a heap. This rock rises in mountain ranges from Tibet, passing through the Himalayas to Persia and Egypt, and appears in the Carpathians, the Alps, the south of France, the Pyrenees, Spain, Algeria, and Morocco. In Tibet, the formation reaches 16,000 feet above the level of the sea, and is in many places thousands of feet thick. That wonderful example of human skill and labour, the Great Pyramid, is built entirely of the rock. Yet this limestone is a comparatively recent formation, certainly not earlier

than the beginning of the TERTIARY era; until which time the vast shelly accumulation, now lifted among the clouds, was quietly reposing on the bed of its parent ocean.

In the chapters devoted to Palæontology, the rocks will be considered in the order of their succession, and with reference to the progressive development of life from lower to higher types of organization; but, as a basis for this, it was advisable first to sketch the framework of the structure which has been the home of living beings during innumerable ages.

CHAPTER VI.

THE GLACIAL PERIODS.

Climate of the Arctic regions in past geological times compared with the present—Proofs of its former temperate character in the extinct fauna and flora of the SECONDARY and TERTIARY eras—Former Arctic condition of European climate—Considerations which led to the theory of Glacial action—The physical properties of ice, as exemplified in Alpine and Greenland glaciers and icebergs of the polar seas—Contemporary glaciation of Arctic and Antarctic continents, the Himalayas, etc.—Extension of Glacial deposits to the neighbourhood of London—Astronomical and other theories in explanation of climatic variations—Evidences of the existence of man in Glacial times—Retrospect.

AT the present moment, a very large area in North America and Asia and the intervening islands is subject to a climate so severe that, wherever the elevation of the land is at all considerable, the ice and snow covering it are permanent at all seasons, or only partially melted in summer. In the Antarctic regions these conditions appear to be greatly intensified—judging from the extension of ice northwards in the Southern Ocean, which, while it prevents any satisfactory exploration of the land towards the South Pole, indicates the prevalence of a greater degree of cold than we have experience of in the Northern hemisphere. Without the aid of geology,

it would naturally be concluded that these conditions had prevailed for an *indefinite* time; and doubtless, measuring time by human history, both polar regions have been covered by ice for a long period—probably longer than all historical time. But, in the northern at least, we have the most conclusive direct evidence, in the presence of coal and lignite, of a mild and equable climate within ten degrees of the Pole, so late as the middle of the TERTIARY era. Not only the seam of coal discovered by Sir G. Nares's expedition in lat. 81° 44′ N., but the fossil plants and animals collected by M'Clintock, Sherard Osborn, etc., testify to the prevalence, in that part of the globe, of a climate far more moderate than that of Great Britain, at the time when such life was possible: the *Sequoias*, or gigantic pines of California, are represented by numerous fossil examples in Greenland, for instance; and the cypress (*Taxodium*) of the Southern States of America, in Spitzbergen; while shells of the ammonite, and portions of extinct reptiles, associated elsewhere with a temperate climate, have been brought from the Parry Islands, imbedded in Jurassic strata. Some geologists have assigned a climate as mild as that of Lombardy to these islands in Jurassic times, and not without good grounds. No less than thirty species of fossil plants, none of them now living anywhere within the Arctic circle, were brought from Grinnell Land, between lat. 81° and 83° N., by the British Arctic Expedition of 1875–6.*

* The most northerly point reached by the sledges was lat. 83° 20′ N., in long. 63° W.

Among these were species of cypress, pine, willow, elm, poplar, birch, etc., and one species of fresh-water lily. From the latter we must conclude that stagnant water, unfrozen for the greater part of the year, was once present at this extreme northern limit; while the warmth-loving cypress flourished on land which is now permanently encased in ice. Judging from the presence of these animals and plants in rocks of Oolitic and Middle TERTIARY age, we cannot but conclude—whatever may have taken place in the interval—that these were periods of warmth, and that the land surface was clothed with abundant vegetation of all classes, from reeds, rushes, and water-lilies in the swamps and lakes, to hard-wood trees on the hills and uplands of Grinnell Land and North Greenland.

We must either put aside all our knowledge of the relations between animal and vegetable life and temperature, and account all physiological science baseless, or admit that these organic beings were influenced by the same laws of temperature which prevail now; and as a consequence that the climate in which they existed had a mean annual temperature of not less than 50° Fahr., its mean now being scarcely 2° above zero! More recently still (see Chapter XII.), the north coast of Siberia was inhabited by immense numbers of animals closely allied to the elephant, possessing an organization intolerant of extreme cold, and requiring for their support abundant vegetation throughout the whole year. With the advent of a severe climate they, too, perished; for the advance of that rigorous cold which extinguished

the vegetation of the Greenland coal forests would also have deprived these herbivorous animals of the means of subsistence; and not one of the vast multitude survived until a more favourable change again took place, when the ice sheets disappeared, and Northern Europe assumed its present comparatively temperate climate. Any conclusions, then, as to the permanence of climate, founded on present experience added to the records of human chronology, are fallacious. It did not for a moment occur to the early navigators of polar seas that the lands which they saw locked in ice could ever have sustained an almost tropical vegetation, or that the sea, crowded with icebergs, could have given birth to the delicate ammonite. Desolation frowned grimly from the glaciers and perpetual snows of Greenland, along whose shores once grew the dense forests of a coal formation, and the impression was that as the scene appeared to them so it had always been. Still less, perhaps, can the traveller, passing through the smiling valleys of the midland counties on a fine August day, realize the scene presented when a sheet of ice covered the whole landscape, and never yielded even to the midsummer sun. If he could then have coasted the shores of Wales and Scotland, he would have found every considerable valley and inlet blocked by an enormous glacier, bearing slowly along with it masses of rock torn from mountains many miles away; while the Hebrides would have looked like great rough hillocks of snow and ice rising from the sea, and hundreds of icebergs drifted away from their shores into the Atlantic.

That such was formerly the condition of the British Isles, of the whole Scandinavian peninsula, and of other parts of Europe, Asia, and America, probably as far south as the 50th parallel of latitude, no geologist has any doubt. Repeated observations of certain distinctive marks upon rock surfaces, and certain peculiar deposits of gravel, stones, and clay, together with blocks of rock unlike anything in their neighbourhood, distributed along the courses of valleys, and even perched upon the slopes and crests of hills, gave rise to the suspicion that some hitherto unrecognized form of geological action had operated in the production of such remarkable results. None of the already known mechanical agents —water, vulcanism, upheaval, or subsidence—could be made to interpret the phenomena; though, for some little time, while we were groping in the dark, it was maintained that sudden elevations of the beds of surrounding oceans had launched immense volumes of water upon the land, which had not only carried masses of rock, weighing many hundreds of tons, miles away from their parent formation, but carved out longitudinal grooves of every size, from that of a pencil-point to the breadth and depth of some feet, in granites, sandstones, and basalts.

The more thoughtful of observers could not rest content with an explanation which satisfied so few of the conditions of the problem, and entirely failed to account for the transportation of masses of granite, over several intervening ridges of limestone or slate, into a far-off valley, or left them suspended upon the slope

of a mountain, to whose rocks they were entire strangers. Water might move materials of very considerable weight down a mountain's side, or along the fall of a valley; but it was altogether inconceivable that a mass as large as "Cleopatra's Needle" should have been carried by it up the side of a ridge, and deposited in the valley on the opposite side. Whatever agent moved the giant boulder in the Devil's Glen, County Wicklow—a block of granite measuring some 27 × 18 × 15 feet, and now resting on a hill of Cambrian slate—over a wide intervening valley, quite six miles from the nearest granite rocks, it could certainly not have been water. In other respects too, the inundation theory was found to be untenable.

Meanwhile it was discovered that the rocks of Norway presented the same appearances as those of the British Isles, and wherever contemporary glacier action was studied—in Greenland, Spitzbergen, or the Alps—the conviction began to gain strength that to ice alone must be attributed all the phenomena which had hitherto baffled scientific investigation.

Before describing these more in detail, it may be useful to consider the leading physical properties of ice, as determined by observations and experiments carried out by Forbes, Faraday, Geikie, Tyndall, etc.

In the first place, the apparent rigidity of ice is not real. It may be moulded into statuettes or vases, by slow pressure, and bars of it may be tied into knots in virtue of the property of regelation which it possesses, so long as its particles are kept in contact by pressure. Thus, a quantity of small pond ice closely packed into

an ice-house freezes into a compact body. Snow, which is simply a loose aggregation of ice-crystals, becomes hard under pressure, and is the principal source of those vast bodies of ice which we know as glaciers—consolidated snow, in reality. It is obvious, then, that the accumulation of snow on mountains—where it melts only partially, even in summer, and where evaporation is at its minimum—can go on for ages, while it gradually forms a cap of ice, amounting to hundreds of feet in thickness—or, as Professor James Geikie estimates, in the case of the west coast of Scotland in former Glacial times, 3800 feet. Sir Wyville Thomson believes the ice-cap of the Antarctic continent to attain a thickness of 1400 feet at the least, and he is the latest observer in this region. Where rain never falls, but all the condensed moisture of the atmosphere comes down as snow, and where this melts at the most for a few hours daily in summer, and on the surface only, new layers are added year after year, the mass is continually increasing, and the resulting glacier and cap ice may readily be supposed to be of great age. In all parts of the world, the formation of ice presents the same general characteristics, and produces similar effects upon rocks. But are these accumulations of ice stationary? Not by any means. Given the slightest perceptible slope, and ice moves over a surface, however rugged it may be, at a rate proportional to the incline, which has been ascertained to be about twenty-five feet annually in some cases, and in one Greenland glacier, observed by Dr. Hayes, a hundred. Let us take the case of a glacier

formed high up in a mountain gorge, having a considerable slope towards a valley or the sea. The gorge turns to right or left, and its sides are everywhere studded with prominences of rock, sufficient, it would seem, to arrest any movement in the glacier. But, as we have seen, ice accommodates itself to a mould under pressure, and it equally readily follows the windings of the gorge, and literally *flows* downward. The glacier is in effect a river of ice, and it obeys in these movements the same law as water. The middle of the ice moves more rapidly than the sides, and the surface faster than the bottom, and the line of quickest motion trends over from side to side at every bend of the gorge. Entering the main gorge may be many tributary gorges, from each of which comes a new glacier to join the main body, and contribute its "moraine" of stones and *débris*, gathered by its edges from the mountain's side, to be deposited along the middle of the trunk glacier. Now some of the Alpine glaciers are known to be 500 feet thick—yet they are pigmies compared to those in the fjords of Greenland—and the pressure upon the rocks beneath this enormous mass must be equal to at least twelve tons on the square foot. What effect the motion of such a weight would have in grinding, polishing, and grooving even granite, by means of rough pieces of rock imbedded in the ice and dragged along beneath it, may be conceived.

Slowly creeping down its valley to the sea, the glacier is at length pushed over the edge of a cliff and breaks off or advances far out from the shelving land, and, being

lighter than water, has a tendency to float. Then the strain between the part still resting on shore and that immersed in the sea becomes too great, and a huge mass, perhaps half a mile long and of great depth and breadth, is parted from the parent glacier, becomes an iceberg, and floats away from the shore. But it goes away loaded with quantities of rocks and earth, which either fell upon the glacier from the sides of the mountain or were picked up by its edges during its passage down the valley. For years it may drift hither and thither, but sooner or later is carried by winds and currents into the temperate zones, where it melts and drops its "spoil" on the floor of the ocean. Dr. Scoresby counted vast numbers of icebergs drifting southwards from the polar seas, some of which showed an altitude of 200 feet above the water, and could not, therefore, have been less than 1500 feet from top to bottom. Of these many were loaded with rock and soil, amounting, he conjectured, to 100,000 tons. Icebergs are being thus formed on the largest scale on the coasts of both polar continents, as they were in earlier times on those of Norway and Great Britain—a fact of which we become assured when we examine the appearances on our native rocks, and the "moraines" and boulders distributed over several counties right in the heart of England. By comparing the two classes of phenomena together—those actually present wherever ice is at work, and those of precisely similar character observable where it no longer operates—we are driven to the conclusion that the agent was in each case the same.

Besides the regular and properly designated glacier, there is another form of ice also originating in accumulation of snow, called the "ice-cap." On low coasts where there are few depressions, or where these do not lead to the sea, the comparatively uniform level of the land admits of the formation of a thick sheet or cap of ice, having much less motion than that of a valley glacier. If, however, there should be a gradual slope towards the sea, the ice must move downwards, and eventually break off at the coast-line. The iceberg so formed will be table-topped, as the great majority of those in Antarctic seas are, and so unlike the rugged, irregular bergs which come away from the glaciers of the fjords of the Arctic continent. In the shallow water near land, ice forms on the bed of the sea as well as on the surface, accumulates, and completely locks in the shore. This is sometimes termed the "ice-foot." Where it happens to form under a cliff or high ground, blocks of stone, loosened by frost, roll down upon it, and when, under the influence of strong currents or winds, it breaks away and floats out to sea, these are dropped from the melting ice and scattered far and wide among marine deposits of very different origin and character.

The mechanical effect, then, of ice, in its four principal forms of glacier, iceberg, ice-cap, and ice-foot, upon rocks is to grind, furrow, and scratch the hardest material, and to transport large blocks of it great distances. The moraines before referred to are accumulations of *débris*, either gathered by the edge of the glacier in its progress down the valley, or fallen upon it from

the sides; and their presence in Great Britain is evidence of Glacial action in this country. They are to be seen lying in long lines upon the Alpine glaciers, but when the ice descends below the level of perpetual frost, and melts, they fall out, and are deposited in long and lofty ridges on the surface of the earth at various angles to the line of descent—sometimes about parallel to it, and at others across the valley like an entrenchment. Wherever such mounds were found in England, they created much speculation, and were actually referred by many to military operations, while the country folk attributed them to supernatural agency. Their composition varies from that of irregular stones to sand and gravel, and their course may often be traced over the dark brown heather by the brighter green of the grass, due to the better soil they contain.

The glaciation of Scotland, Ireland, and the north and middle of England must, apparently, have been on a scale little less magnificent than that of Greenland; for Professor James Geikie has traced the striæ and rock-markings on the west coast of Scotland and the Hebrides to such a height that he believes the Minch was filled with ice of more than 3000 feet in thickness. Further south, Professor Ramsay has shown that the markings occur in the valley of Llanberis, in positions which indicate a glacier or other body of ice, 1300 feet thick. Striation of rock surfaces is of so striking a character that, when once seen, and compared with the marks left by a passing glacier, it can never be mistaken for anything but the action of ice. The grooves and

scratches run mainly in one direction and over considerable obstacles, which are, however, small relatively to the vast mass of ice. Obeying the law of flowing water, ice, when in sufficient quantity, surmounts a hill, much as a stream flows in a curve over a boulder whose top is above the general level of the current, the impetus of the stream behind forcing the water against the face of the boulder, where it receives a momentary check, and is urged upwards and over the obstacle. Ridges and hills have thus been surmounted by the whole body of advancing ice, and the grooves it has cut in the rocky bed may be traced up one face of the elevation and down the opposite. If an observer were to station himself at the foot of a ridge a hundred feet high, lying north and south, and it were pointed out to him that the striations were to be seen maintaining a general easterly and westerly direction on both its flanks, he might feel some difficulty in believing that angular rocks, though firmly imbedded in ice, could have been moved up the incline. We may suppose the base of the ridge to be situated midway between a point some miles off, where the land is 1000 feet higher, and another where it is 1000 feet lower than the place of observation. The total fall of the land will then be 2000 feet, and the ridge only one-twentieth of the whole—quite an insignificant proportion. A cap of ice 500 feet deep, moving along this great general incline, would encounter in the ridge an obstacle no greater relatively than a stream five feet deep would have to overcome in a boulder one foot high lying in its bed. It will be seen at once that

such a ridge could offer no real impediment to the movement of a body of ice five times its height being pressed onwards down an incline, from an elevation of 1000 feet, by a mass extending for miles, and of so plastic a nature that it flows, however slowly, in the same manner as water under the influence of gravity, which is of course the primary cause of motion, and at the same time exerts a pressure of twelve tons per square foot.

Still, the reader may inquire doubtingly whether there really exist at the present moment on any part of the earth's surface conditions at all similar to the above, which we have described as having prevailed in this country. The question may be answered by extracts from the accounts of travellers who have endeavoured to penetrate the interior of Greenland. Among the first of these was Lars Dalager, in August, 1747. His party had ascended a glacier in one of the fjords, at the top of which they arrived exhausted with fatigue. Hitherto they had only been travelling over the ground bordering the *mer de glace,* or over some defluent glaciers; but now an extensive prospect burst upon their view on all sides, striking them with astonishment, particularly when the vast fields of ice were seen stretching across the country in the east coast, bounded in the distance by mountains whose tops were covered with snow, like those on which they stood. The intense severity of the cold, together with the unlimited expanse of ice before them, determined them to return. Late in October, 1860, Dr. Hayes attacked the great glacier in Port Foulke, encamping the

first night at its foot in a temperature of 11° Fahr., and arrived next day at the summit, whence he succeeded in penetrating about seventy miles inland, always upon ice and compacted snow, not a trace of the true rock surface being visible. The temperature was now 34° Fahr. below zero at night, the elevation being 5000 feet above the sea, in the midst of a vast frozen desert immeasurable to human eyes. Such a terrible blast of wind then swept over the ice that they were compelled to descend for their very lives. Dr. Rae made an attempt in 1860, but, after fighting his way for four days up the water of a fjord blocked by ice, encountered a storm of snow which threatened to sink his boat, and never reached even the foot of the glaciers. In July, 1867, Dr. Robert Brown, with a well-equipped party of Arctic travellers and Eskimo set out from the neighbourhood of Jakobshavn to gain the interior of the Illartlek glacier. At an elevation of 1600 feet "the top was flat, and the rocks smoothed by the action of the ice, with blocks perched in all sorts of critical positions. To the south and west were low mountains, rounded and ice-shaven, with snow lakes in the hollows; but to the east there lay a sea of ice without any apparent bounds—a prairie of snow and ice without aught but the horizon to break the view, as dreary a deathlike waste as human eye ever looked upon."

"Greenland has no interior—at least, if we look upon its interior in the light of something else than ice and snow. Solid land or rock there is none now to be seen. The country seems only a circlet of islands

separated from each other by deep fjords or straits, and bound together on the landward side by the great ice-covering which overlies the whole interior, and which is pouring out its overflow into the sea in the shape of glaciers and icebergs. Cross over that surrounding circlet of outskirting island, and we ascend to a plateau where nought can be seen but ice. No fragment of stone is there; no sign of vegetation, except a trace here and there of the red snow-plant; not a sight or sound of moving thing—nothing but hard glacier ice stretching north and south and westward after you have lost sight of the land you have crossed over, and eastward as far as the eye can see. How deep this ice overlies the country it is impossible to say; in some places, I doubt not, many thousand feet."

The latest attempt, in July, 1878, was rewarded with no greater success. Lieutenant Jensen endeavoured to reach the high land of the interior, and, though it was the middle of summer, he encountered a snowstorm which lasted for six days. At an altitude of 5000 feet, and forty-five miles from the sea-coast, the ice, covered by loose snow, extended in every direction; glaciers lay in every depression; and not the smallest speck of land free from ice was to be seen in the vast, dreary prospect.

This is the picture of Greenland, as painted by those who have had a glimpse into the awful wilderness which no human being has ever yet penetrated. All over Scotland and the north of England are blocks of granite "foundlings," or "erratic boulders," doubtless transported by shore ice or icebergs while the country was submerged.

Then it was probably a circlet of islands—of which the crests of the mountains and higher ground only were above water—bound together by a cap of ice, whose fractured edges contributed the icebergs which carried those boulders into the straits and fjords, and dropped them in submarine valleys, or left them perched upon the sides and summits of ridges, which have since been elevated above the level of the sea, to become unimpeachable witnesses to the glaciation of the country.

Few navigators have penetrated far into the barrier of bergs which surround the land of the Antarctic continent; but they all agree in describing this barrier as much more formidable than that of the North Polar ocean. Sir C. Wyville Thomson supposes that this so-called "continent" is partly low continental land and partly a collection of islands bridged together by a continuous ice-cap, at least 1400 feet deep, with here and there somewhat elevated mountain chains. Around this land extends a fringe of ice, having a perpendicular cliff averaging a height of 230 feet above the sea level, bordered by a "floe" some twenty feet thick, which in summer breaks away and becomes a heavy drifting pack, mingled with icebergs which are generally tabular. These facts are the result of observation, and depend in no way upon conjecture. The conclusions drawn from them are that the table-top bergs were formed by the piling up of successive layers of snow during a long period of accumulation, while the ice-cap was slowly forcing its way over the low land, and out to sea over a long extent of gentle slope along the bottom, to a

depth of more than 200 fathoms. Being then unable to resist the strain of its buoyancy, it would break off somewhere near the shore-line in large portions, and float away as a tabular iceberg. During its transit it had gathered, principally on its lower face, quantities of stones, rock-fragments, and earth, which became gradually scattered over the beds of surrounding oceans, and are continually brought up by the dredge. The nearly uniform height of these bergs suggests that the land on which they were formed is comparatively flat, and, as the portion of ice above water affords an approximately true measure of its whole depth, that must be the *least* depth of the ice-cap from which it proceeded, viz., 1400 feet; and the pressure it exerts on the land surface over which it moved must have been little less than a quarter of a ton on the square inch—a force to which the hardest rock must necessarily yield to some extent. The ice, it is true, yields more easily than the rock, but the action of the former is continuous. Over any given spot on the rock, angular imbedded fragments are dragged by this stupendous force; when one has passed, another succeeds, and to this another, century after century, without intermission. Time gives power to the feeblest agent—*gutta cavat lapidem, non vi sed sæpe cadendo*—and, if the fall of single drops of water will hollow out a rock, and the pattering of human feet will wear a granite step, the irresistible march of the glacier or of the ice-cap may well be credited with all the stupendous effects claimed for it.

According to calculations by Dr. James Croll, based

on the thickness of the ice which comes away from the permanent sheet extending round the North Pole, and allowing half a degree as the slope over which it moves, the ice at the Pole itself must be twelve miles in thickness! It was clearly proved by the latest British Arctic Expedition, that the proper place of the sea from lat. 83° northwards was completely usurped by continuous ice, rising in high hillocks like a turbulent sea suddenly frozen. Yet this ice is being continually pushed southwards by successive accumulations around the region of the Pole, and we cannot conceive of it moving at all except under very great pressure from the northwards. Thus Dr. Croll's estimate appears by no means excessive.

The great mountain axis of the Old World affords examples of contemporary glaciation nowhere equalled outside the polar regions, as far as is yet known. At an elevation of more than 20,000 feet in the Mustagh range of the Himalayas are two glaciers adjoining one another, with a united length of 65 miles; and in the neighbourhood a third, 25 miles long, reaching from an altitude of 24,000 feet downwards to 16,000 feet, where it ends in a mass 250 feet deep and three miles in breadth. Here, too, are all the familiar features of rock-sculpture, moraines, and glacial clays, similar in all essentials to those exhibited wherever the action of ice is in operation—the same story told on the heights of the Himalayas as that which may be read every day in Greenland or the Alps.

It is impossible to speak otherwise than vaguely of Glacial periods in the now temperate zones of the world,

of when they began and when they ended, and of the intervals which occurred between alternating periods of the advance and retreat of the ice. Comparisons between the rock-markings, the boulders, the moraines, and the clays of the British Islands and other temperate regions, and identical appearances in still glaciated areas, leave no room for doubt of the primary facts; and there is evidence of *inter*glacial periods, when plants and trees grew upon old Glacial clays, which were subsequently covered by fresh masses of ice-borne material. Such beds occur in Lanarkshire, for example, where we find layers of peat, tree trunks, the remains of the mammoth and other land animals, overlaid by more Glacial clay—the upper beds of which contain *marine* shells, many of them now confined to Arctic seas—and boulders transported by icebergs. Here, then, is the history of three periods; first, one of submergence, when the floating ice deposited its burden of fine material, the result of the trituration of rocks over which it had passed; then a second, of upheaval above the sea-line, and the growth of a vegetation sufficient to feed large herbivorous animals; and thirdly, of resubmergence, when shell-fish, partly of a temperate and partly Arctic character, had possession of the sea, and boulders were left on the bottom by floating ice. Finally, the land was again raised; these shells, with their Glacial clay-bed, were lifted some 1500 feet above the sea to the position they now occupy. And, as we cut through the beds, we come successively upon the shells and boulders, the plant and animal remains, the boulder clay, and,

at last, the bottom rock, with all its ruts, grooves, and scratches, just as the ice-cap of the first period had sculptured it.

Though the northern and midland counties of Scotland and England have been the great scene of glaciation, its characteristic deposits are found in patches in Buckinghamshire, Hertfordshire, Essex, and Middlesex, to the northern slopes of the ridge bounding the valley of the Thames—round Watford, Barnet, Finchley, Hendon, and Muswell Hill. Formerly these accumulations of clays, sands, gravel, etc.—containing fragments, often angular, of granite, limestone, and chalk, from more northerly formations, with a heterogeneous assortment of fossils proper to the Jurassic and Cretaceous rocks—were looked upon as an inexplicable congeries of material, associated together somehow by the action of water. The labours of Mr. Searles, V. Wood, junior, and Mr. William Whitaker, among others, have, however, restored order to this chaotic collection; and it is now fully understood that these localities formed part of a submerged area, over which the floating ice from the more northerly elevated land distributed the fragments of rocks and fossils (as strangers). At this period of the glaciation of Great Britain, icebergs and ice-rafts must have floated over the spots where the parish churches of Hendon and Finchley now stand. There they probably grounded on submarine ridges, and left their burden of stranger rocks and fossils, with the fine clays scraped from the surface of more northerly lands, on the district which is rapidly becoming covered

with the homes of busy workers in the great metropolis of England.

Indisputable as are the proofs of these extraordinary and prolonged variations of heat and cold in the climate of the earth, at least since Jurassic times in the Northern hemisphere, there is no evidence to fix their precise geological limits, though there is every reason to believe that further inquiry will elucidate the question. Glaciation of northern Europe had probably reached its maximum in the Pleiocene era, and possibly extended, in a less degree, to a later date. Some geologists have maintained the prevalence of similar conditions in far earlier times, dating back from the Cretaceous to the Devonian and even Silurian epochs; but everything suggestive of glaciation at so distant a time is necessarily uncertain, and may be delusive. Rocks belonging to all these formations have been laid bare, and subsequently covered by quite recent deposits. In their denuded condition they might obviously have become truly glaciated, and the traces of this could have been masked by very recent accumulations. Thus, Silurian rocks might be glaciated—as they actually are—but it does not follow that they were so affected at a time coincident with their own age, or even nearly approaching it. So much uncertainty, indeed, surrounds the determination of the range in time of these periods of extreme cold, that nothing can be gained by attempting to define their most remote limits, while the data we have are so liable to misinterpretation.

Through what cosmical changes has it been possible

that Arctic ice could have descended into the very heart of Europe, *after* the lapse of an epoch during which Greenland brought forth abundant forests, and could have again retreated to its present boundaries, leaving the area it once enveloped fit for the habitation of man and the growth of exuberant vegetation?

Among the various explanations advanced are three, which may be termed the astronomical, the volcanic, and the atmospheric, all others being subsidiary to these. Dr. James Croll has ably maintained the astronomical view, according to which the orbit of the earth has been subject to great eccentricity at irregularly recurring periods, and that this, combined with the precession of the equinoxes, has completely revolutionized the seasons—giving, during one period, a long and cold winter, and very brief summer to the Northern hemisphere, with the reverse to the Southern; and, during another period, a long summer and short winter to the Northern, and the reverse to the Southern. In the former case the general disposition of the wind would, owing to well-known atmospheric laws, be from north to south, pushing back the warmer tropical waters from the Northern hemisphere, and a glacial climate would prevail there; while in the latter the general movement of winds would be from south to north, the waters of the tropical belt would be carried towards the north, and the climate become warm. The winds would certainly have the motion described, in virtue of the laws by which air from a cold area flows over to the warmer, and would thus contribute towards

the results indicated. Tens of thousands, or even hundreds of thousands of years may fairly be assigned for the recurrence of these great secular summers and winters, due to the varying eccentricity of the earth's orbit and the varying position of its axis. That such changes have taken place, within smaller limits, during the short human period, we have positive proof in the discrepancies between the present apparent places of certain stars, and their positions as given by earlier astronomers, and which it cannot be doubted were the true positions for their time; so that there is a sound basis in experience for the astronomical theory advanced by Dr. Croll. The objections to it are mainly negative and it affords one of the best explanations of all the climatic changes yet proposed. The volcanic is much simpler, and is founded on past experience of changes of temperature occurring within the body of the earth itself. Thus, it is supposed that at long intervals the heat beneath the surface of the Northern hemisphere greatly increased, and subsequently greatly decreased, impressing at one time a tropical and at another a glacial character on the climate, through both the water of the ocean and the atmosphere. Others, on the contrary, believe the constitution of the atmosphere itself to afford a sufficient explanation. The sun is considered to be a cooling body, and consequently to have imparted more heat to space and the bodies moving in it, in former times, than at present. The singular luxuriance of the vegetation of the Carboniferous era suggests the presence there of an excess of carbonic acid gas and moisture in

the air, which have subsequently been fixed by the growth of plants and disposed of in chemical combinations, leaving the earth a less dense atmosphere, and less capable of retaining heat. Assuming the facts to be such, and the deductions from them to be valid, which is very much open to question, no provision is made by this view for extreme cold; unless we add to it the supposition that there are regions in space of very different temperatures, and that, in the great movement of translation through space which the whole of our system is undergoing, our planet has passed through regions of heat and cold alternately, with a corresponding effect upon the climate of the bulk of the land lying on either side of the equator.

No one, it may be presumed, will hesitate to admit that archæologists have traced the evidences of man's existence back to a period long anterior to any contemporary written or even traditional history; and philosophy places no restrictions on the field of research. She demands only evidence for any reputed discoveries, and allows these to be worked out to their legitimate conclusions, however subversive they may prove of opinions formed before that evidence was forthcoming. The archæologist has as good a title to pursue his inquiries into the antiquity of man through all geological time as is freely granted to the palæontologist, who desires to trace the succession of animal forms over the same field. Already the contemporaneousness of man with the extinct mammoth has been proved by the association of their bones in the same caverns and

strata, and, with still greater certainty, by rude representations of the living animal made by human hands; and in one case flint arrow-heads were found embedded in the carcase of a mastodon, in the State of Missouri. These instances carry the antiquity of man back to a very distant time at all events, and we know, besides, that these extinct animals were living in Europe before the last Glacial epoch. But implements of stone, fashioned by man, are also found in deposits of undoubted Glacial origin, belonging to *recent* TERTIARY times no doubt—but, in comparison with our chronology, enormously remote. The evidence for man's presence in Europe during or prior to any Glacial period is small in amount, but distinct so far as it goes, and all we know of the natural history of the period is corroborative rather than the contrary. Implements designed with intelligence and executed with skill occur in many parts of Europe, and they must be either contemporary with or anterior to the deposits in which they were found; and when these gravel and clay drifts can be shown to have been formed by ice, the presumption becomes very strong that the makers of the implements occupied the country while a large portion of it was still in the embrace of the ice, and surrounded by an ocean in which floated boulder-carrying bergs.

Looking back through the long vista of time which stretches from the Pleistocene deposits of the later TERTIARY formations to the far-distant Laurentian, the mind entirely fails to grasp the vastness of the interval. It is as impossible as to realize the idea of space,

though each period had its distinct limits, its special forms of life, and often widely different physical features and climate. Cradled in incandescent gases, and bathed in steam; the first sediments of its early deposits probably laid down in boiling oceans; its surface pitted with millions of outlets for its internal fires; its exterior presenting a rugged outline, more savage and desolate than any existing volcanic region, and literally "without form and void,"—the earth grew with exceeding slowness into definite shape. Battered unceasingly by rain, river, and ocean, the sharp angles of the primitive rocks took rounded forms; and the cataract, leaping a thousand feet from the precipice, carved its way through the rock until it became a mountain burn, one of ten thousand feeders to a mighty river. Through immeasurable cycles of time, water performed its part in planing down the surface irregularities and piling up the waste elsewhere in a finely divided condition fit for the growth of vegetation, mingling the carbonates, phosphates, and silicates in due proportion, and gathering together the food of plants. Meanwhile, the now cool oceans were beginning to give birth to lowly forms, which in their turn built up, from the materials of the worn rocks suspended in water, masses of limestone, which were one day destined to be raised into mountain chains. Ever progressing towards organization through the unceasing labours of its lowliest creatures, the earth was no longer a wilderness of scorched rocks, ashes, and lava; but, as early as Devonian times, began to put on that lovely clothing of vegetation which culminated in

the singular beauty of the Carboniferous landscapes. Could we be transported to the scenery of this latter period, we should be struck by its uniformity in widely different latitudes, no less than by its extraordinary luxuriance, in which it vied with the densest of tropical jungles. As far as we can judge from the evidence collected, this was a period of sluggish rivers, with extensive flats and broad estuaries, presenting the most favourable conditions for the development of plant life, and a surface far less diversified by mountain and valley than at any subsequent period; comparatively free from disruption, but undergoing a gradual alternating movement of depression and elevation—so gentle, indeed, that the most fragile parts of the plants are often preserved as perfectly as if they had lain in the cabinet of a collector, and the venation in a May-fly's wing is still as delicately beautiful as when the insect broke from the prison of its pupa-case on the surface of the water, and flitted away in the sunlight, to enjoy its ephemeral existence.

In summing up the factors of geological action, we may accord the first place to mechanical agents, but must not lose sight of the biological. The microscope tells us in no doubtful terms that we may attribute all the coralline limestones, the greater part of the chalk, and the widespread and enormously thick nummulitic limestones to the agency of insignificant marine animals; while the vegetable origin of coal is equally beyond question. Chemical forces and long-continued electrical action have probably contributed largely to the forma-

tion of metallic ores, but the data are not sufficiently precise to admit of conclusions as certain as those derived from the mechanical and biological evidences which abound in all stratified rocks.

Destruction and reconstruction have followed each other in endless succession, since our planet emerged from the condition of a gaseous body and began to assume that of a solid. The physical forces have, to borrow a metaphor from agriculture, repeatedly broken up the surface as with mighty ploughshares, and prepared the water, no less than the land, for the habitation of organisms so diversified in their structure and needs that they could not have existed without a thorough distribution of the elements of life contained in the rocks. Neither, probably, are we less indebted to extra-terrestrial influences for the distribution of at least certain of the limestone formations and coals—those great secular summers and winters due to causes before explained. The summers permitted a much more northerly extension of coral-reef builders and limestone-making foraminifers and of coal-forming plants than would have been possible if the earth had always maintained the same position towards the sun that she now holds. On the other hand, the winters broke down vast quantities of the older rocks, and glacial action spread the fertile "tills" or boulder clays over a large area in Europe. Strictly speaking, the evidence for these cycles of heat and cold is not clearly traceable further back than Jurassic times; but astronomers see no inherent improbability in the presumption that they may have

covered the whole of geological time. From whatever point of view we contemplate the history of the earth, the instability of the conditions—whether mechanical, biological, or climatic—to which it has been subjected, stands forth prominently. The story is simply that of changes wrought by instruments employed over and over again in building up and pulling down every portion of the fabric, to rear a yet more perfect structure upon the ruins—more clearly indicative of the force of the Creative impulse, and ever tending towards the production of new phases of life.

> The hills are shadows, and they flow
>   From form to form, and nothing stands.
>   They melt like mist; the solid lands
> Like clouds they shape themselves and go.
>
> There rolls the deep where grew the tree.
>   O earth, what changes hast thou seen!
>   There, where the long street roars, hath been
> The silence of the central sea!

PART II.

PALÆONTOLOGY.

THE PALÆOZOIC ERA.

THE MESOZOIC ERA.

THE KAINOZOIC ERA.

CHAPTER VII.

THE CONTINUITY OF LIFE.

Explanation of the term—The domain of palæontology—The records of geological time—Nature and character of fossils—Cases of remarkable preservation—Fossils represent extinct species—The laws of succession and descent—Inferences from fossils as to the distribution of sea and land—Imperfections of the record—Proportion of terrestrial and aquatic forms preserved—Continuity of the zoological scale—The doctrine of evolution of species, in opposition to catastrophism.

The term "continuity of life," placed at the head of this chapter, is employed to express the result of the examination and comparison of all the plant and animal remains discovered in the various formations; whence it has been concluded that organisms of different degrees of perfection have succeeded each other in a long line of descent, broken at several points, but preserving in the main indisputable evidences of progress from lower to higher forms of structure. On the accuracy with which the line of succession is determined, the relation *in time* of one formation to another depends. In itself, a sedimentary rock gives no true indication whether it was formed at the very earliest or very latest period. Thus, a sandstone or limestone of Jurassic age could not be

distinguished by mere mineral composition from one of Devonian, or even Meiocene age; and were we dependent upon lithological characters, the rocks could only be roughly classed in accordance with the nature and proportions of mineral matters contained in them, and we should have before us an accumulation of almost meaningless facts, which would tell us no more than that some rocks had been formed from minute particles of carbonate of lime, others from small grains of silica, etc., and that water had probably been concerned in the special arrangement of their constituents. Further than this it would be impossible to go, and the true history of the earth must for ever have remained a sealed book. But we are not thus left in ignorance, for each rock of the sedimentary class contains clear records of its position in the series, and from a careful comparison of these we reach trustworthy conclusions as to the relations of rocks to one another in the great scale of existence.

Fossils are the records of life on the earth—the remnants of its past botany and zoology—the foundation of palæontology or the "science of ancient living beings." No indications of the presence of life can be found in the igneous or fire-formed rocks, as will be obvious from their origin; * but they abound in those of stratified character, and, within certain limits, serve as sure guides to the determination of the relative ages of the formations in which they are present.

A fossil may be described as the trace of the existence of any once animated being, preserved in the rocks, and

* Fossils may, however, be *accidentally* included in lava.

the most untutored mind would generally have no hesitation in recognizing it as such from its resemblance to living forms. It may be a mere fragment, or it may be perfect so far as its hard parts are concerned—the shell of a mollusc, the backbone of a fish, the skeleton of an animal, or the leaf or stem of a plant. Further, there may be internal or external casts of such objects as shells, which have fallen upon an originally soft deposit. In the first case, the deposit, hardening, will have given an impression of the inside of the shell; and in the second, one of the outside; while the calcareous shell itself may have been dissolved by chemical action, its place being occupied by other material. Impressions of the footprints of birds and animals, of raindrops, and even the ripple-marks of water, may also be classed as fossils, and they are valuable indications of the conditions which prevailed at the time when they were made. As a general rule, fossils may be fairly assumed to be contemporaneous with the deposits in which they occur; though, in later times especially, it has frequently happened that richly fossiliferous rocks have been broken up and become partially recemented, when the older fossils are found associated with the new formation as intruders among those properly belonging to the latter. This, however, will not vitiate the general conclusion that any fossil imbedded in a rock belongs to the life-period of the deposit containing it.

If a fossil were presented to us for examination without any previous knowledge of its history, we should observe that the shell, bone, or wood had undergone an

extraordinary change. It is no longer in the form of lime or wood, comparatively light and soft, but exceedingly heavy and hard. Decomposition has removed all the animal or vegetable matter—the fibres, tissues, and muscles—and nothing but the skeleton remains; and even this is unfamiliar to us as the substance of any shell we may pick up upon the sea-shore, or of a bone bleached by the sun. Tested chemically, it is silica in some cases, in others iron pyrites, or some mineral not proper to the original organism. In fact, these minerals have penetrated it entirely, entering into the minutest recesses, and usurping frequently the whole of the structure; so that it may be said no part of the animal or plant remains, only an exact representation of it in another material. Apparently these minerals must have been in solution in water, and have thus infiltrated the organism, whose present aspect is that of a mass of flint or stone, combined, perhaps, with bisulphide of iron. Between this extreme case of fossilization and a recent shell, bone, etc., there are various degrees, depending on the greater or less quantity of mineral matter with which the organism has come into contact; and, as a general rule, the remains from the older rocks are more completely fossilized than those of, for example, the Cretaceous period, though some few of the oldest have not been so greatly changed. On the other hand, among deposits of the TERTIARY era, fossils are often only slightly penetrated by foreign matter, and, under exceptional circumstances, the gelatine has not altogether disappeared from the bones, and traces remain of the actual tissues

of animals and birds. Nothing of this kind can be expected to occur in the earlier rocks, where it is rare to find any remnant of the actual organism, beautifully as the form of it is often represented by the intruding material.

In coal, displacement of the original matter has not proceeded so far, for most of the carbon remains; but specimens of plants completely silicified are very common, and, when cut and polished, exhibit the grain of the wood in the most perfect manner. Some instances of remarkable preservation have already been noticed—the wings of insects and the spores and fronds of ferns. In the Mesozoic formations chiefly occur vast quantities of *coprolites*—the fossil excrements of fishes and aquatic reptiles—which have recently been largely used as manure, on account of their richness in phosphate of lime, derived from the food upon which the animal subsisted. They present accurate casts of the intestine, and sections of them show scales, shells, and teeth, the products of the animal's last meal. The stomachs of the great aquatic reptiles of the Mesozoic era sometimes remain to testify to their rapacious habits, and the unborn young has been found included in the abdominal cavity.* As an interesting curiosity, it may be mentioned here that the ink-bag of a fossil sepia has been preserved so perfectly that an excellent drawing of the creature was made with the ink which, during life, it used to cover its retreat under a black cloud from an enemy. Still

* Professor H. G. Seeley is now investigating the viviparous character of Enaliosauria.

more insignificant creatures have left evidences of their presence in ancient seas. The tracks of sea-worms are familiar objects in sandstones, and the lithographic slates of Bavaria retain the impressions of the bodies of jelly-fish cast ashore on the fine mud of an Oolitic estuary.

Fossils mainly represent extinct species of animals and plants; but the great types to which they belong have always survived. Throughout the history of the earth, fluctuations in the tide level of life have repeatedly occurred; nevertheless it has been steadily rising during all time. In Laurentian times, it was at its lowest, and appears gradually to have advanced in three successive waves of molluscan, reptilian, and mammalian forms, severally represented in the PRIMARY, SECONDARY, and TERTIARY eras, culminating in man. We can point distinctly to a time when nothing approaching a mollusc had appeared, to another when no living creature among many species possessed a backbone, and to a third when none suckled its young. First among recognizable organized beings, the foraminifers have persisted through all the formations, and are with us now; so have their immediate successors, the molluscs, as a group, though some remarkable members of it are extinct. Hence it would seem that the lower organizations have the best chance of surviving, through the very comprehensiveness of their type. More complete and highly specialized forms have departed, while these, the starting-points of structural progress, are left to indicate the line of ascent to more complex types. That such an ascent is much more than an ingenious hypothesis, no palæontologist

will now dispute, even if he holds that it does not explain the almost sudden appearance and disappearance of some large groups. We cannot pass from one formation to another, either upwards or downwards, without encountering the strongest suggestions of lineal relationship between the fossils of rocks in superposition.

Let the figures 1, 2, 3, 4, 5, 6, represent all the superimposed formations, No. 1 being the lowest and No. 6 the highest of the series. Each will contain more or less characteristic fossils—not a heterogeneous collection, such as might be made by indiscriminate mixture of all the animals in a natural history museum. In No. 4 the leading forms will resemble those in Nos. 3 and 5, immediately below and above it, more closely than those in Nos. 1, 2, and 6; while those in Nos. 1 and 6 will differ immensely from each other and the rest. Between the extremes we have the whole zoological scale, corresponding completely in all fundamental types with that adopted for living organisms. Such order and arrangement cannot, then, but indicate a primary *law*, operating over the vast period included in geological time. At one extremity we see man, at the other a mollusc or foraminifer. Gradations, rising through crustacea, fishes, reptiles, birds, up to mammalia, fill the interval. The general or comprehensive type always precedes the special and complex, and affinity forms an indissoluble bond of connection between the lowest and highest.

To this may be added a potent argument for the derivation of living beings from common ancestral types.

Von Baër pointed out that the young of animals resembled the genus to which they belonged more nearly than the species or the individual; or, in other words, that the embryo possessed the characters common to the group, assuming those of the individual only at the adult stage,—an observation which has been fully confirmed by Dr. Charles Darwin and others. As a supplement to this law, it is found that a highly organized animal possesses, during the embryo stage, structural characters which become obliterated at maturity, but which were fully developed in and were all-important to some primitive creature of the same class throughout its whole existence. These "remnants" of structure carry us back to a common ancestor; while we are carried forward, by cases of *anticipated* organs, to forms which had not yet appeared above the life-horizon in their full characters; for, in the SECONDARY era, we have reptiles with the wings of birds and true powers of flight, and, in the TERTIARY, birds which have not lost the teeth of reptiles.

Some isolated facts have yet to be brought within the embrace of the law of succession, but the positive evidence for its continued operation far outweighs the negative, and every zoological sub-kingdom affords instances in which the signs of lineal descent admit of no question. In the biology of the past, the key to that of the present must be sought. We see large classes of animals flourish for a considerable time and then vanish, and again some persist for very extended periods. We know nothing of the laws of extinction.

The night of obliteration has fallen upon many species, when we have not been able to mark its advancing shadows. On the other hand, sometimes the first faint glimmer of dawn in the life of a species is perceptible, and is never lost until the new form attains its noon-day development; and either passes into the darkness of extinction, or remains to throw light upon the zoology of the present.

If all living organisms were gathered together to receive from the hand of the palæontologist certificates of their age, he would assign to some (and those invariably the lower forms) an immense antiquity, while he would point to others which had no existence in comparatively recent times, but which have now no superiors in organization and special attributes. The Cambrian or Silurian world, were it recreated for us, would be a new world—not because of the prevalence of unknown forms, but in virtue of the absence of the most prominent existing forms. The sea would not contain any approach to a whale, nor the land any animal so highly organized as a mouse or a bird. Ascending, however, to the Cretaceous—just before the great outburst of contemporary life—the aspect of land and water is totally changed, and we have a splendid legacy, from the intermediate periods, of reptiles both winged and wingless, of creatures not far distant from true birds, of fishes of the highest orders, and of plants not inferior to the oak, beech, and cypress. Had all the intermediate forms which led up to these been concealed from our view, then the doctrine of sudden and

simultaneous creation of new types could have been maintained with some show of probability. The boldest theorist would hardly have dared to bridge this vast biological gulf with the law of continuity.

From fossils are drawn conclusions as to the prevailing physical conditions, climate, and distribution of land and water at a given period, founded on the comparison of living species whose habits of life are known, with those of similar structure of which like habits may be predicated with tolerable certainty. Hence the proportion of terrestrial and aquatic animals in any formation affords an approximate idea of the relative proportion of land to sea and fresh water at that period; and, judged by this standard, water would appear to have predominated over land to a far greater extent in early than in later times.

A system of rocks takes its place in the order of time on the ground that it contains an assemblage of fossils broadly characteristic of that system, in whatever part of the world it may be found—that is to say, *more* characteristic of it than of any other. In some instances, however, the identity of a group of rocks may be known at once by fossils peculiar to it and to no other. The *Graptolites* thus occur only in Silurian rocks, and that curious oyster form, the *Gryphæa,* in great force in the Jurassic; but the general classification is independent of such exceptions, for it rests upon a foundation including many orders, genera, and species, widely distributed over the globe during their life-period.

From the above it must not be concluded that the life-zones are separated by distinct lines of demarcation. On the contrary, they interpenetrate each other to a very considerable extent. It is no more possible to say exactly where such a zone began or ended, than to distinguish precisely the upper and lower limits of two rock-systems lying on each other. The systems may pass, by scarcely perceptible gradations, into one another for some distance, and the life-zones may overlap in both directions, the characteristic features of each becoming gradually more strongly marked, until it can be said with certainty that we have advanced into a new region. On every geological horizon new forms rise into view and others pass out of sight; and when once extinction takes place, there is no subsequent revival. Notwithstanding the apparent breaches of continuity in both the formations themselves and their life-zones (due more probably to our deficient knowledge than to an actual condition), the evidences of physical and biological continuity are so clear in many instances that we cannot but believe this to have been the universal law. Whenever a great physical break occurs (such as that between the Cretaceous and Eocene strata), there is a corresponding gap in biological sequence. A number of new forms *seem* to have come suddenly into being, while many others equally remarkable have disappeared entirely. But what has become of the intermediate strata, with their fossils? They have been broken up by denudation, the Eocene rests unconformably on the Cretaceous; a page of the history has been

torn out, and its fragments irretrievably dispersed. In these circumstances, the record cannot be expected to be perfect, and there is no possibility of obtaining a complete series of the animals and plants which have inhabited our globe, though inferences from the whole body of facts lead to the conclusion that it *was* complete. Here and there are preserved the grand outlines of a scale of zoological succession, whose details are sometimes indistinct, sometimes altogether wanting—outlines so definite that we cannot hesitate to regard them as the framework of a system, comprehending all organic beings that have ever existed, and relating them by the closest ties of affinity with the living types surrounding us.

The surface of the land has suffered so much through alterations of level and denudation, that its organic products have had less chance of preservation than those of sea, lake, or river. Indeed, they owe their uninjured state entirely to the protecting agency of the sediments deposited in water, in by far the great majority of instances. On the breaking up of a tract of land, many of its remains must necessarily be destroyed by mere attrition in water, those which escape destruction being carried into ocean-beds and estuaries, or large fresh-water lakes, and covered. With marine animals and plants the case is very different: they live and die on the spot, and are there entombed once for all; whence it follows that the zoology of the water is vastly better represented in all periods than that of the land (with the exception, perhaps, of the Carboni-

ferous and some portions of the TERTIARY formations, whose terrestrial flora and fauna are better preserved than usual). Wherever fossils of land plants or animals are found in aqueous deposits, it may be taken for granted that they are not very far from their place of habitation during life, because, with individual exceptions, they would soon find a resting-place near the coast which produced them. Thus it is often possible to construct a hypothetical map of any period, showing the distribution of land and water with some approach to accuracy. Yet we can never become more than partially acquainted with the life of land, lake, or river, owing to the frequent breaking up of the land, with attendant dispersion of many of its fossils, and the comparatively small area of fresh water.

Unless every fact which will be marshalled before the reader in the succeeding pages be part of a chain of extraordinary delusion—an inconceivably persistent arrangement of evidence leading to a false conclusion; unless palæontology be the only branch of human science which renders unsound deductions from sound premises inevitable, and stultifies all man's powers of observation, comparison, and generalization,—we must perforce admit that the law of *continuity* has governed the succession of life throughout all time. The testimony may often be imperfect, but in no single instance where we are fully possessed of it does it contradict the law; and it is utterly incorruptible. We appeal to a fossil or a series of fossils to answer a definite question, and we may obtain no reply; but

when the answer is given, it is clear, decisive, and ever in one direction. We are persuaded, beyond the possibility of reasonable doubt, that a continuous series of sedimentary deposits must have been formed from Laurentian times to the present; and that they included a perfect record of every form of life before they were broken up and dispersed—their fossils destroyed by erosion in water, or so metamorphosed by heat as to have suffered complete obliteration. Here the evidence is wanting only; but while it may frequently be so deficient as to afford no support to the hypothesis of succession, and must therefore be considered negative, no series of mechanical or biological phenomena can be so connected as to sustain for a moment the view of the older geologists, that sudden "catastrophes" have effected revolutions in the distribution of land and water, sweeping away whole groups of animals, and replacing them by new and totally distinct types. We do, it is true, meet with wide intervals in the zoological scale, and if our knowledge extended no further, they would be fatal to the law of succession; but, as the scale is followed backwards, the types become more and more simple. There is no apparent reason why the bones of a marine mammal, such as a whale or porpoise, should not have been preserved among those of the numerous fishes of Devonian times, the strata of which have been most diligently explored, but as a fact there is no trace of them. Why do mollusca appear first, succeeded by crustacea, then the lowest class of vertebrates (fishes), followed by the lowest of amphi-

bians, and these latter not until the Carboniferous, their highest members appearing only in the TERTIARY era? Why should the chelonian reptiles make their appearance before the saurian, and both these before birds? How is it that certain hoofed quadrupeds should have preceded others, in a line ranging from the tapir-like *Palæotheria* of Europe, through many intermediate forms structurally prophetic of the horse, which does not appear, however, until all of them have become extinct? What are we to think of the remarkable chain of proboscidians (*Deinocerata*), with characters partly elephantine and partly ruminant, existing prior to true elephants and stags—a host of large herbivorous creatures, which had died out before the rhinoceros or hippopotamus had come upon the scene? We are, indeed, met at every step by an apparent continuity, which, if it be not substantially real, is a most extraordinary delusion.

At the same time, it cannot be contended that the doctrine of evolution is all-sufficient. As a working hypothesis, it enables the palæontologist to classify and compare his facts, and to give them a *meaning*, intelligible within the limits of our knowledge at least. It may at some future time be abandoned, as have many successive astronomical theories, doing in the mean time good service by concentrating thought upon well-defined points. The zoologist, dealing with living forms, has, perhaps, surer ground for confidence than the palæontologist, groping among the fragments of shattered strata; but he never can complete his genealogy without help

from the latter. He cannot with confidence pronounce that the apteryx of New Zealand was a separate creation for those islands, but finds himself thrown back upon the past, when large tracts of land were occupied by groups of which this is a mere remnant. He knows that the apteryx is the only living representative of its gigantic congeners, the moas, in New Zealand; but he does not know how much submerged land, which bore the same forms, may lie hidden beneath the Southern Ocean; while in Asia, Africa, and America, birds, possessing great similarity of structure, and especially the characteristic shield-like breast-bone, still abound. The evolutionist tells us that these forms, though they appear to us completely isolated, have remained over, in the areas they now occupy, from a far larger group; and, if we could strip the ocean from the earth, we should probably find them continued into long since subsided lands. Their isolation, then, is apparent only; and the whole field of geology supports his conclusion. During the great "reptile age," the distribution of land and water must have been such that, had a zoologist been called upon to make a list of existing species, he would have had as much reason as now to point to seemingly distinct creations, or rather, as the evolutionist views the question, to the occupation, by singular creatures, of isolated areas geographically distant, though, not so long previously, united. When living marsupials first became known, they astonished and perplexed naturalists beyond measure. Separated by the whole expanse of

the Pacific Ocean, they might indeed have been regarded as distinct creations for America and Australasia respectively; but the fact of their existence on opposite sides of the globe, and in no intermediate area, was itself a circumstance pointing to once conterminous geographical and zoological boundaries. By-and-by the geologists found them as fossils in the Oolite of Europe, proving them to be nothing specially extraordinary. They have disappeared from Europe, and remain only in America and Australasia. Distinct as are the Arctic types of mammals, some at least of them, as the reindeer and lemming, have had a range amounting to thirty degrees of latitude southwards of their present habitat; yet, if we judge by their now restricted limits, they might have come suddenly into existence and have been wholly confined to the Arctic regions. Asia and Africa, again, alone possess, in our day, true elephants; but we have only to strip off the surface of almost contemporary accumulations, to find closely related species occupying the most prominent position among the herbivora of Northern Europe and America, to the very verge of the Arctic circle.

So long as the zoologist had before him a small body of facts, admittedly remarkable in themselves and unconnected with the past history of the globe, he had no alternative but to explain them by a law of creation operating suddenly for the production of new and vastly advanced forms. He has now abandoned this ground, because the palæontologist has shown him organisms

advancing by successive steps towards the isolated beings which had excited his astonishment, and led him to an erroneous conclusion.

It should scarcely be a question with us how far our sense of the Creative power is affected by the consideration of this subject. If it be most true that all living beings are the result of a continuous, instead of sudden impulse of creation, then it is undoubtedly most noble, and the human mind must eventually recognize the fitness of truth in whatsoever guise it may present itself. Dr. Charles Darwin, every page of whose works is instinct with an earnest spirit of reverence for Creative power, concludes "The Origin of Species" in these eloquent words—

"Authors of the highest eminence seem to be fully satisfied with the view that each species has been independently created. To my mind it accords better with what we know of the laws impressed on matter by the Creator that the production and extinction of the past and present inhabitants of the world should have been due to secondary causes, like those determining the birth and death of the individual. When I view all beings, not as special creations, but as the lineal descendants of some few beings which lived long before the first bed of the Cambrian was deposited, they seem to me to become ennobled. As all the living forms of life are the lineal descendants of those which lived before the Cambrian epoch, we may feel certain that the ordinary succession by generation has never once been broken,

and that no cataclysm has desolated the world. There is a grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning, endless forms, most beautiful and most wonderful, have been and are being evolved."

THE PALÆOZOIC ERA.

CHAPTER VIII.

THE LAURENTIAN, HURONIAN, CAMBRIAN, AND SILURIAN LIFE-PERIODS.

The beginnings of life—Graphite a possible result of vegetation—*Eozoön*, the earliest animal form—Increase of molluscan and crustacean types—Lingulæ, graptolites, trilobites—The earliest plants—Scales of fishes, traces of vertebrata.

WHO shall say when life began? Can it even be determined whether a plant or an animal was the first organized being? We speak of the PALÆOZOIC era provisionally, for, so far as our knowledge goes, it is the era of "ancient life," the earliest examples of which occur in the Laurentian rocks. As these, the oldest known of the stratified series, were deposited in water, denudation must have prevailed for an indefinite time, in order that they might be accumulated, and their parent rocks might have contained fossils of which every trace is lost. Mineral carbon (graphite) abounds in them, and is probably not less in the aggregate than

the vegetable carbon of the Carboniferous strata. It is quite conceivable that the Laurentian graphite, familiarly known as "black lead," is the residuum of plant life, completely metamorphosed by heat, pressure, and the long lapse of time; and the character of the iron ores in these rocks is suggestive of the influence of decomposing vegetable matter. Whether or not the Laurentian lands were covered with forest, of which there is yet no direct evidence, the sea appears to have been peopled by one form of animal life—named, from the great development of these rocks in North America, *Eozoön Canadense*. Here, at least, the microscope reveals a foraminifer—a member of the group of lowly creatures which contributed so much to the formation of the chalk—whose remains are arranged in laminæ consisting of carbonate and silicate of lime. By most of the ablest microscopists it is considered to be a veritable organism—this view being held by Dawson, Logan, Carpenter, Williamson, Parker, Gümbel, etc.; while Möbius has recently given reasons for the opinion that it is inorganic.* However this may be, it occurs in countless multitudes, and we cannot very well imagine that these seas were totally barren of life, especially when we can trace the accumulation of other rocks, rich in carbonate of lime, to the agency of foraminifera. The creature which heralded "the dawn of life" appears to have collected organic matter about its jelly-like

* A monograph on Eozoön is now being prepared by Carpenter and Dawson, in which further evidence for its organic character will be adduced.

protoplasm, and to have deposited it in the form of vast reefs, in a manner similar to that of the coral polyp; but its title to rank as an organism at all is necessarily indistinct, on account of its immense age and the defacing action of metamorphism. Principal Dawson has

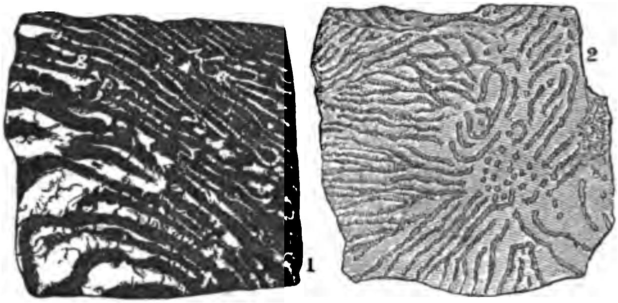

FIG. 7.—*Eozoön Canadense.* 1. A section showing the layers, actual size. 2. The canals, magnified 100 diameters (after Dr. Carpenter).

noticed, besides, worm-burrows and traces of another foraminifer (*Archœospherina*) in Laurentian rocks.

At present the position which should be assigned to the Huronian series is so doubtful, and the life-history of these rocks so little known, that nothing would be gained by a discussion of the subject; and we therefore pass on to the Cambrian period, rich in forms which, though zoologically low, are very distinct. The two curious fossils named *Eophyton*, the "dawn plant," and *Oldhamia*, after Dr. Oldham, may probably be regarded as the representatives of marine vegetation, if eophyton is not a land plant. Though some consider these coralline structures, there can be no doubt of their organic nature. Sponges of simple character, and sea-

worms abound, and the *Echinodermata* are represented by species of sea-lilies and star-fishes, and shell-fish by the genus which gives its name to the *Lingula* flags; but the most important feature of this period is the appearance of the first articulated animals—the crustacean forms of water-fleas; and the *Trilobites* related to the king-crabs, no doubt the most mighty and predatory family of the time, living in shallow waters, and becoming entombed by millions in the mud.

FIG. 8.—Fronds of *Oldhamia antiqua* (natural size); Lower Cambrian.

Rising hence to the Lower Silurian, we come among a few doubtful fucoids (sea-weeds), true sponges, a gigantic foraminifer (*Stromatopora*) allied perhaps to eozoön, corals and *Graptolites*, *Brachiopods* (lamp-shells), circular-chambered shells of nautiloid form; the straight *Orthoceras*, star-fishes, and swarms of trilobites of higher structure, while some traces of fishes are found in detached bony scales. This was the culminating point of trilobite life, beyond which they become indistinct, and finally pass out of existence. But the ascent in the zoological scale does not stop with these first articulated forms. In the upper strata of the formation we have unquestionable sea-weeds, and an

undoubted land plant (*Lepidodendron*), which subsequently becomes of such importance in the Devonian and Carboniferous periods, together with small bodies which Sir Joseph Hooker has identified as the seed vessels of a species of club-moss; besides a possible

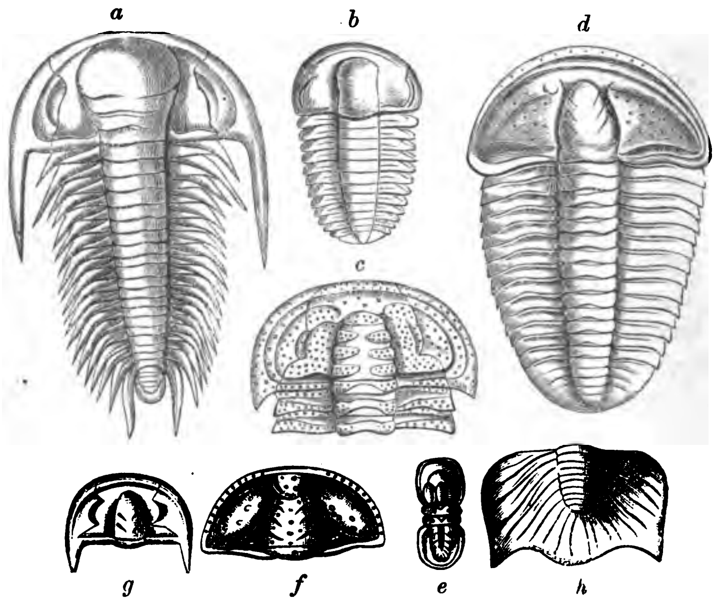

FIG. 9.—Cambrian Trilobites. *a. Paradoxides Bohemicus; b. Ellipsocephalus Hoffi; c. Sao hirsuta; d. Conocoryphe Sultzeri; e. Agnostus rex; f.* Head-shield of *Conocoryphe Matthewi; g.* Head-shield of *Dikellocephalus Celticus; h.* Tail-shield of *Dikellocephalus Minnesotensis.*

conifer and other plants in North America. The corals are now becoming more complex in structure, and the species more numerous, while the graptolites as a group are fading away. Among echinodermata, the "sea-lilies"

are conspicuously abundant; masses of the most beautiful limestone having the stalks and calices of these crinoids scattered throughout the rock in profusion. Of the crustacea, the trilobites still remain examples, but there is now added to them a gigantic crustacean with very distinct swimming-paddles, and arms bearing at their extremities claws similar to those of a prawn. This formidable creature, *Pterygotus*, was frequently six

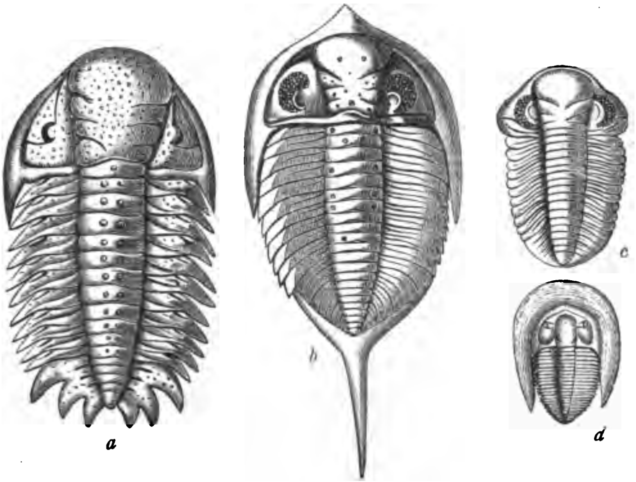

FIG. 10.—Upper Silurian Trilobites. *a. Cheirurus bimucronatus; b. Phacops longicaudatus; c. Phacops Downingiæ; d. Harpes Ungula.*

feet in length, and must have swept the Upper Silurian seas undisputed by any rival, except, possibly, the fishes, which are represented only as yet by scales and curious head-shields, and are believed to belong to the ganoid group of the sturgeons and gar-pikes. If these are remains of fishes, then we have the first appearance of

any vertebrate, and that of the lowest type, though not until all the inferior classes of marine animals had subsisted for a prolonged period.

Reference has been made to the oil-bearing shales, and the theory that their hydro-carbons are distilled from the countless numbers of Silurian trilobites. In any case, this was the culminating period of their existence, distinctively the "Age of Trilobites;" and the museums contain specimens of rock almost wholly composed of densely impacted trilobites. The rocks of the system are widely distributed, and have yielded oil in Europe, Asia, and America abundantly. They stretch through Wales, Cumberland, Westmoreland, the south of Scotland, Ireland, and France; through Scandinavia, Russia, Bohemia, Asia Minor, Northern India, Australia, New Zealand, and both Americas; yielding gold, silver, platinum, mercury, tin, manganese, and other metals or ores. Though the life of the period was distinctively marine, and widely extended oceans prevailed, large continents must necessarily have existed to provide material for the accumulation of these rocks. Palæontologists do not even despair of eventually finding evidence of considerable vegetation, and of the presence of true fishes; although there is no probability that anything will be found to invalidate the broad principle of the succession of life. Since it is believed that we are already acquainted with the predominant forms, it is scarcely likely that any additions to the list will include organisms of more advanced type than a lepidodendron or a fish.

CHAPTER IX.

THE DEVONIAN, CARBONIFEROUS, AND PERMIAN LIFE-PERIODS.

Distinction between "Devonian" and "Old Red"—Coal seams—Vegetation of the period—Placoid and ganoid fishes—Carboniferous vegetation, mollusca, crustacea, fishes, amphibia, and insects—The Permian period—Disappearance of sigillaria—First appearance of true reptiles—*Proterosaurus*.

Below the Carboniferous is an extensive and important series of rocks, formerly known under the name of Old Red Sandstone; in contradistinction to the sandstones, etc., immediately above the Carboniferous—now forming the Permian and Triassic groups, but originally classed as New Red Sandstone. Whether we elect to accept the term Devonian as inclusive of all the rocks belonging to the sub-Carboniferous series, or retain the name "Old Red" for a portion of them, the distinction is of little importance in relation to their age. They belong in all probability to the same life-period, though this distinction may be drawn between the Devonian and Old Red: the former seem to represent deep-sea conditions in America, Europe, and Britain; while the latter are probably shoal-water deposits—possibly, in some cases,

of inland seas—in Canada and Scotland. Practically, they may be regarded as contemporaneous, representing different geographical areas and dissimilar local influences. The great majority of geologists accept this view, advanced by Murchison and Sedgwick, and it is likely to be retained until a much fuller acquaintance with the distribution of the rocks and fossils of the system may afford ground for modifying it.

Devonian rocks, it should be observed, occur in large districts in South America and Australia, as well as in Europe and North America. Here for the first time we find coal-seams, indicative of an abundance of terrestrial vegetable life, which is wanting—or at least as yet unknown—in any former period. Most of the examples of fossil plants have been obtained from the Gaspé rocks of the Old Red division—a fact which helps to fix the character of these sandstones as shallow-water deposits; and where they pass upwards into the Carboniferous system, there is little distinction between the flora of the two periods. Ferns of several species, tree ferns of large size—lepidodendra, sigillaria, calamites—a singular plant named by Principal Dawson *Psilophyton*, from the Devonian of Canada, and a tree trunk a foot and a half in diameter (*Prototaxites*), besides the exogenous forms *Dadoxylon* and *Ormoxylon*, afford conclusive evidence of the prevalence of extensive tracts of land richly clothed with vegetation.

Not less remarkable is the advance in marine life. True sponges, corals of various forms, and, among shellfish, *Spirifera*, *Atrypa*, *Strophomena*, *Spirorbis* (a tube-

inhabiting sea-worm), and the chambered shells *Clymenia* and *Goniatites* are prominent objects. Of the trilobites, most of the genera are survivals, but in *Phacops latifrons* we have an apparently new and widely distributed form; and the small *Cypridinæ*, whose fossil bodies constitute masses of slaty rock, further exemplify crustaceous life. The graptolites, as a group, have now disappeared, and are never revived, although one insignificant inhabitant of existing seas (*Dictyonema*) may be a faint representative of this great Silurian family.

But Devonian zoology is richest in marine vertebrates —fishes of the two great placoid and ganoid groups,

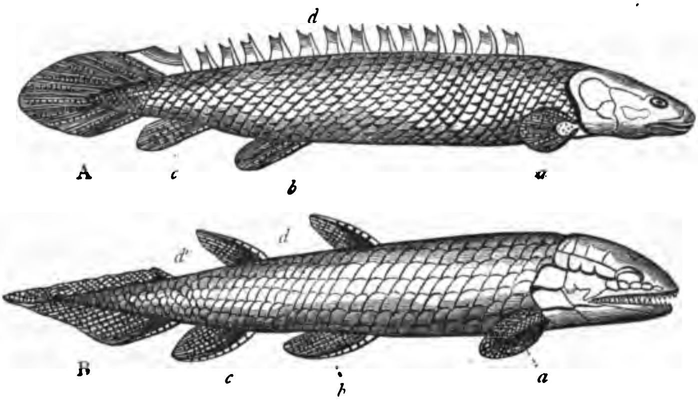

FIG. 11.—A. *Polypterus*, a recent ganoid fish; B. *Ostolepis*, a Devonian ganoid fish; *a. a.* pectoral fins, with rays surrounding a central lobe *b. c.* ventral fins; *d. d'.* dorsal fins, with a spine in front.

represented respectively by sharks, dog-fishes, skates, and rays; and by sturgeons and gar-pikes. Both groups are distinguished by an almost wholly cartilaginous

skeleton, a tail whose lobes are more or less unequal in size, and bony plates on the skin, instead of the horny scales of the majority of fishes with bony skeletons. The Devonian sharks are not of the predatory class which dominate the seas of our time, but more closely related to certain existing tropical forms, whose teeth are adapted for crushing shell-fish rather than for capturing an active prey, and their fin rays are usually armed with defensive spines. The greater number of these fishes were certainly marine; but there are some among the ganoids which probably inhabited the brackish water of estuaries, or the higher fresh-water reaches of rivers, like our sturgeon, which, however, has both placoid and ganoid characters. No doubt it is extremely difficult to classify fossil fishes accurately in accordance with the scale for existing types; but if our sturgeons had any true prototypes they were probably the characteristic forms of *Cephalaspis*, *Pterichthys*, and *Deinichthys*, bearing on the head enormous shield-like plates of a more or less bony consistence. The last seems to have been of large size—fully twenty-five feet long—and the jaws were armed with a formidable array of teeth, two of which were huge trenchant fangs, well calculated to hold any co-tenant of the waters of the period. To the same group may be added the genera *Onychodus*, *Ostolepis*, *Holoptychius*, etc. No true teleostean, or bony fishes having an ossified skeleton, a tail with lobes of equal size, and overlapping horny scales, as in the salmon and perch family, have yet appeared; and, singularly enough, are not known until the Cretaceous

period, when the far higher forms of amphibians and reptiles had already become well established, when reptiles had assumed some of the most important characters of birds, and a terrestrial member of the great mammalian class had inhabited Triassic woodlands.

Teeming with life as were the Devonian waters, the forest-covered lands must surely have sustained some creatures higher than the insects of the North American rocks, which are the first and only known representatives of terrestrial life. Judging from their wings, these insects seem to have belonged to the orders *Orthoptera* (locusts, etc.), and *Neuroptera* (May-flies, etc.), and one of them, *Platephemera antiqua*, was a giant of his kind, being five or six inches across the expanded wings. Another, *Xenoneura*, clearly possessed the "drum," or stridulating membrane, with which many familiar orthopterous insects call their mates, or challenge their rivals to battle.

Devonian fossils have manifestly suffered extensive destruction, and it is quite possible that we have in these insects only a very small part of the record of the terrestrial life of the period. Since one of the orders is carnivorous in a certain stage of its metamorphosis, this implies the probable co-existence of other insects as its food. And were there no primitive reptiles or amphibians, to prey upon these insects? Was the land so barren that it brought forth no air-breathing creature higher in organization than a dragon-fly or a grasshopper? To these questions palæontology can at present give no answer, and unless our knowledge of the

life-history of the time should receive very important accessions; the Devonian period will continue to be designated as the "Age of Fishes."

Lying conformably (or without any severe dislocations) on the Devonian, are the Carboniferous rocks, consisting of sandstones, limestones, and shales, together with some heterogeneous sedimentary deposits, interstratified with seams of coal, which are sometimes extremely thin, but occasionally attain a thickness of twenty feet. The physical conditions under which these vast accumulations of mineralized vegetable matter took place have been described in Chapter V. Three leading varieties of coal are—Anthracite, containing about 2·84 parts of hydrogen and 1·74 of oxygen; Bituminous, containing 6·21 hydrogen and 21·23 oxygen; and Lignite, containing 8·37 hydrogen and 42·4 oxygen, in each hundred parts, the remainder being carbon, with traces of iron, sulphur, lime, and silica. Notwithstanding the far greater proportion of carbon in some than in others, the vegetable origin of all is indubitable, although the character of the plants from which they were derived may have differed, and it is quite certain that subsequent changes have affected the original vegetable mass in unequal degree. From the following figures it may be judged how immense a store of fuel has been laid up for us by the plants of a period whose vegetation seems to have been more abundant than that of any other in the life-history of the earth. Thus, the coal-fields of China, almost untouched at present, are estimated to cover an area of 400,000 square miles, and those of the United

States 200,000 square miles. In the year 1878, according to the report of the Inspectors of Mines, no less than 134,179,968 tons of coal were raised in the United Kingdom alone. The plants were mainly of the flowerless order, consisting of lepidodendra, sigillaria, calamites, and ferns, gigantic representatives of the

FIG. 12.—Examples of Carboniferous plants. 1. *Sphenopteris;* 2. Fern frond; 3. *Calamite;* 4. *Lepidodendron;* 5. Stem and bark of *Sigillaria;* 6. *Stigmaria* (root of *Sigillaria*).

araucarias, club-mosses, horse-tails, etc., of our time, and some plants exhibiting stems with concentric rings of wood and other characters, which seem to bring them near the flowering cycads or false palms.

Many of the limestones, etc., of America and Europe

of Carboniferous age, not actually closely associated with the coal formations, were apparently of marine origin. On the other hand, those in close contact with the coal-bearing deposits contain fossils of obviously terrestrial plants and animals, indicating shallow fresh and brackish waters of very large extent. Foraminifera abound in the marine strata, corals maintain a high place, crinoids are conspicuous forms in the lower limestone series, sea-urchins have numerous representatives, shells of spirorbis are found attached to plants, and the great nummulite group, so prominent a feature in later periods, is foreshadowed by a beautiful little shell (*Nummulina pristina*) from the Belgian limestones. The typical Silurian and Devonian crustacea no longer retain their prominence, eurypterids and trilobites sinking for ever below the horizon after this period. But they are succeeded by the higher forms of ancient king-crabs (*Limuli*), and by crustacea possessing ten free limbs, a carapace, and an abdomen similar to existing lobsters, etc. The types of shell-fish are, on the whole, of a higher order. Here we have the numerous *Productæ* with goniatites and *Ammonites*, the latter making their first appearance on the scene. Fishes of large size, such as the genera *Rhizodus* and *Megalichthys*, with faint reptilian characters, but still belonging to the ganoid and placoid groups, head the list of Carboniferous marine fauna.

Few as the individual signs are, they are, however, sufficient to indicate that the forest-covered lands teemed with life. Scorpions, spiders, and centipedes infested

the trees, and the insects which flitted among the foliage were beetles and May-flies, of which latter class one was of gigantic size. Imbedded in the silt which filled the hollow stems of sigillaria, have been found the first air-breathing molluscs, two or three forms of land-snails exemplified by *Conulus priscus*. Among terrestrial vertebrata, no trace of which had been presented in the Devonian, are amphibia with well-ossified bones, and teeth of peculiar labyrinthine structure, whence they have derived the generic name of *Labyrinthodonts*. Some of these were of very considerable size, the head of the genus *Anthracosaurus* measuring eighteen inches in length and twelve in breadth at the junction with the body.

Entering now the Permian period, the general aspect of life remains unchanged with one notable exception—

FIG. 13.—Coal-forming plants. The two outer figures are portions of stem of *Sigillaria*; the middle figure is an unexpanded fern frond. *a.* bark; *b.* the wood beneath.

the disappearance of sigillaria, while other associated plants of the coal measures still flourished. The amphibia remain in full force; but purely air-breath-

ing vertebrates, genuine reptiles, are known for the first time in the history of creation. Here are apparently the earliest instances of terrestrial vertebrates with four limbs adapted for progression on land, undergoing no metamorphoses like the amphibia, but springing from the egg already equipped with permanent organs of locomotion and respiration—animals altogether more specialized in structure than any that had preceded them. Excluding some forms whose title to be considered of Permian age is doubtful, the genus *Proterosaurus* (first lizard) takes the leading place among the reptiles of this

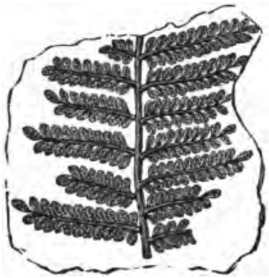

FIG. 14.—Fully expanded fern frond.

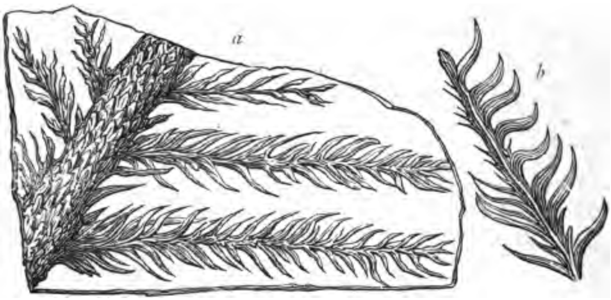

FIG. 15.—*Walchia piniformis*, a Permian land plant; *a.* branch; *b.* twig.

period. On the whole, it may, perhaps, claim most affinity with the crocodiles. Its teeth were sunk in separate sockets, but its vertebræ were constructed on

the same pattern as those of existing fishes, *i.e.* amphicœlus, concave both in front and behind, affording that mobility of the whole of the backbone required by an animal which passes much of its time in the water, and captures aquatic prey. On some of the Permian

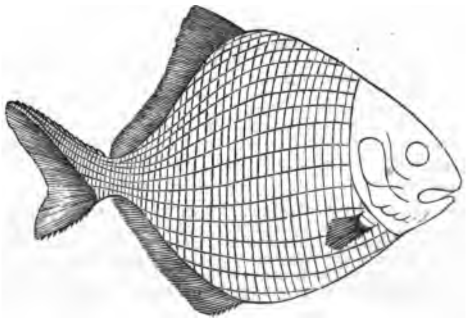

FIG. 16.—*Platysomus gibbosus*, a ganoid fish with the heterocercal tail (Permian).

sandstones, too, are found impressions which may possibly be the tracks of another order of reptiles, similiar to turtles, though these are not known with certainty to have come into existence during his period.

TABULAR VIEW OF THE PALÆOZOIC SYSTEM OF ROCKS, WITH THEIR PREVAILING OR CHARACTERISTIC FORMS OF LIFE.

PALÆOZOIC, or PRIMARY.	PERMIAN.	Typically developed in Russia and Germany, fairly in Britain; known also in North America. New Red Sandstones, Marls, Magnesian limestones, Dolomitic Conglomerates. Plants similar to Carboniferous. Marine life generally similar. No Trilobites. First appearance of a true reptile—the lacertilian form, ***Proterosaurus***. Footprints, possibly of turtles.
	CARBONIFEROUS.	Extensively developed in all quarters of the globe. Carboniferous, or mountain limestones, Coal, interstratified with sandstones, limestones, ironstones, shales, and clays. Millstone Grit. Fossil plants in great abundance—Ferns, *Lepidodendra*, *Sigillaria*, *Calamites*, obscure Conifers, and, possibly, *Cycads* or false palms. *Foraminifera* abundant. Sponges. *Lithostrotion* (an abundant coral), *Echini* (sea-urchins), and *Crinoidea* (sea-lilies), *Limuli* (king-crabs), *Decapods* (lobsters), *Ostracoda* (water-fleas), and *Mollusca* (shell-fish) abundant. Fishes of the shark and ray families. *Labyrinthodon* (an amphibian) *Arachnida* (spiders and scorpions), *Coleoptera* (beetles), *Neuroptera* (May-flies). *Trilobites* only in America.
	DEVONIAN and OLD RED SANDSTONE.	Developed in Devon, Scotland, France, Prussia, and North America. Sandstones, Shales, Flags, Coralline limestones. Fossil land plants abundant. Ferns, *Sigillaria*, *Lepidodendra* (club-mosses), *Calamites* (horsetails); *Dadoxylon* and *Ormoxylon*, believed to be exogenous plants. Sea-lilies. Tube-making marine worms (*Spirorbis*). Fishes belonging to the families of the Sharks, Rays, and Sturgeons. The first fossil insect, probably belonging to the genus *Ephemera*. Numerous *Trilobites*.
	SILURIAN.	Developed in Wales, Russia, Scandinavia, and North America. Slates, Limestones, Shales, Sandstones, and Conglomerates. Llandovery, Bala and Caradoc, Llandeilo, Arenig, and Tremadoc beds. *Fucoids* (sea-weeds). Corals, sponges, star-fishes, and *Graptolites* (sea-pens) abundant; also *Brachiopoda* (lampshells), chambered spiral shells of nautiloid character, others straight, as *Orthoceras; Limuli* (king-crabs) and *Eurypterida* of giant size. *Trilobites* abundant. Bony plates and scales of fishes. *Foraminifera* referable to existing types. *Annelides* (tube-making sea-worms).
	CAMBRIAN.	Developed in Wales, Scotland, Ireland, Bohemia, Scandinavia, and America. Slates, Sandstones, Schists, and Conglomerates. Tremadoc slates; Longmynd, Llanberis, and Harlech beds; Lingula flags. *Fucoids* (sea-weeds), sponges, star-fishes, and *Crinoidea* (sea-lilies). Burrows of marine worms. *Lingulæ* (bivalve shell-fish). *Trilobites* in vast numbers. *Oldhamia* and *Eophyton*—the former possibly a zoophyte, the latter probably a land plant.
	LAURENTIAN and HURONIAN.	The Huronian rocks are typically developed in North America, and partially in Europe. Metamorphosed sandstones, limestones, conglomerates, and slates. The existence of fossils is doubtful. Some remains have been described as those of lowly organized molluscs and foraminifers. The Laurentian rocks—in some localities 30,000 feet thick—are typically developed in North America; represented also in the Hebrides, Scandinavia, etc. Limestones, generally much metamorphosed, gneiss, mica schist, etc. One fossil foraminifer, *Eozoön Canadense*. Large deposits of Graphite, which may be of organic origin.
AZOIC.	AZOIC.	Granite, Quartz, or similar rocks; probably to be found at the base of the series everywhere, and may be partially or wholly igneous. Often occur at the surface, where they are considered to be "intrusive." Other Azoic (without life) rocks are of volcanic and chemical origin, and not naturally fossiliferous. They may contain fossils derived from other strata.

THE MESOZOIC ERA.

CHAPTER X.

THE TRIASSIC, JURASSIC, AND CRETACEOUS LIFE-PERIODS.

Triassic vegetation, molluscs, fishes, and amphibians—Footprints of labyrinthodonts—Reptiles—Footprints of reptiles, or birds—First appearance of mammals—Jurassic vegetation, molluscs, fishes, and insects—Enaliosauria, deinosauria, and ornithosauria; their structural peculiarities—Crocodiles, lizards, and turtles—Anatomical characters of *Pterodactyl* and *Archæopteryx*—Marsupials—Cretaceous vegetation—Gigantic ammonites and pterodactyls—European and American deinosaurs—Mosasauroids—American bird-reptiles—The Mesozoic climate, and evolution of new forms.

The close of the Palæozoic era seems to have been marked by considerable changes, and a period of destruction of rocks and fossils appears to have intervened between it and the immediately succeeding Mesozoic era. Comparing the fossil remains as a whole, a vast difference will be found between those characteristic of the two eras. Fortunately, a large proportion of the Mesozoic formations consist of calcareous rocks, such as the Muschelkalk and Rhætic beds of the Trias, and

the Jurassic oolites, in which the records of life have been preserved in great abundance. The base of this series of formations corresponds with the upper portion of the New Red Sandstone, as the Permian series does

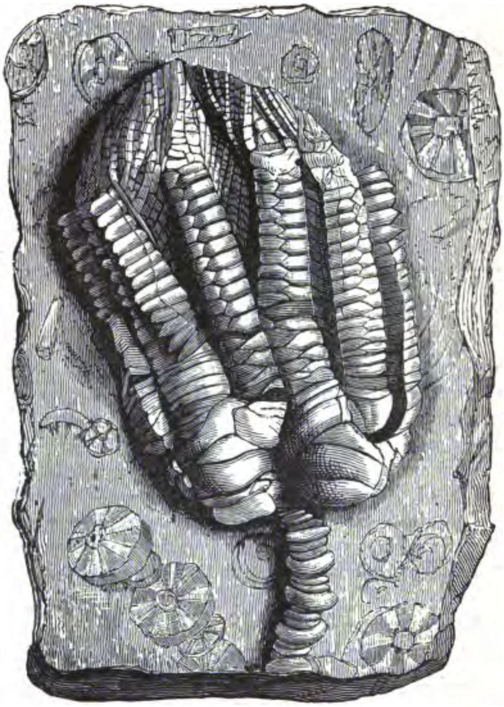

FIG. 17.—Lily *Encrinite;* from the Muschelkalk (Trias).

with its lower members. One of the first facts which strikes us here is the disappearance of several plants which were with us throughout the two preceding periods. Vegetation is now chiefly represented by ferns,

conifers, and cycads—the two last being plants of a distinctly higher order than those which have vanished. Marine invertebrate life is present in great force, but some hitherto numerous molluscan forms have become extinct, notably the productidæ. Among crinoids are the beautiful lily-encrinites of the Muschelkalk, decapod crustacea (lobsters) have their representives, pearl oysters abound, and chambered shells—goniatites, ammonites, ceratites, etc.—are plentiful; but the cephalopod shells, *Belemnites*, have not been known until now. The fishes still belong to the ganoid and placoid orders, with the exception of one genus, named by Agassiz *Ceratodus*, known only by its singular teeth, which are almost exactly like those of the existing "mud-fish" of tropical Australia, a fresh-water vegetable feeder. All the Triassic amphibia are believed to be labyrinthodonts, a group with which we became familiar in Carboniferous times. But some of these were of enormous size, as indicated by the footprints of one originally named the *Cheirotherium*, or "beast with a hand," on slabs of sandstone. A water-newt, with a skull three feet long and two broad and a body in proportion, would probably nearly represent this monster amphibian, though some anatomists have supposed it to be more nearly allied to the frogs or toads, from the character of its skull. But the body was certainly elongated, the hinder limbs longer and larger than the fore limbs, and the belly defended by bony plates. The footprints in the illustration are reduced to one-eighth of the natural size. It seems probable that the animal which left us these evidences

of its presence had walked across a damp tract of sandy clay on the estuary of a river, and that this subsequently dried hard and even became cracked by the sun, as shown in the irregular transverse lines. The place might then have been covered by the wind with dry

FIG. 18.—Footprints of *Labyrinthodon;* occur in the flaggy sandstones of Britain, Germany, and North America (Trias). (Reduced.)

sand, and subsequently overlaid by a fresh deposit during a flood or the return of the tide.

With the Triassic period begins that extraordinary influx of reptilian life, which increases throughout the

Jurassic and Cretaceous periods, and has given to the Secondary era the appropriate title of the "Age of Reptiles." Among these reptiles were some of most remarkable structure, suggesting affinities with turtles and crocodiles, and bearing in some instances additions to the upper jaw, like the canines of carnivorous animals. Such was the character of *Dicynodon*. But *Cynodraco* possessed not only canines, but incisors and molars of carnivorous type. In *Rhynchosaurus* the skull is similar to that of an aquatic bird, the jaws having been probably covered with a horny sheath; and the head of *Oudenodon* carried a pair of trenchant jaws without teeth. Among crocodilian forms are *Nothosaurus*, whose jaws were extremely long and furnished with numbers of sharp, pointed teeth set in distinct sockets, the head being carried on a long neck; and *Simosaurus*, remarkable for the great size of its orbits. To these may be added the genera *Thecodontosaurus* and *Belodon;* while the lizards are represented by the genera *Telerpeton* and *Hyperodapedon*.

Another series of footprints in the sandstone rocks of the Triassic system in Connecticut, has given rise to much discussion. Are they the tracks of a bird or a reptile? In the first place, it will be seen, on reference to Fig. 19, that the foot has three toes, of which the joints also correspond in number to those of a bird, and the general appearance of the footprint bears out the conclusion that it was made either by a heron, or crane, or some similar inhabitant of sea or river shores. If this were so, the bird must have been a veritable

colossus, for some of the largest of these footprints are over twenty inches long and twelve inches broad. On the other hand, no bird-bones, only those of reptiles, have been found in association with these tracks; and we know that in this and the Jurassic periods the characters of reptiles in many respects approximated to

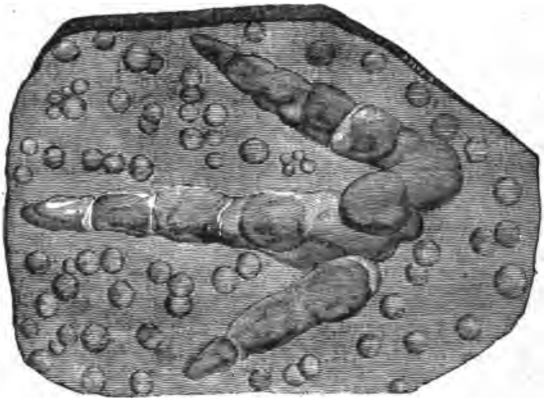

FIG. 19.—Footprint of bird (or reptile ?) from the Triassic sandstone of the Connecticut river, America (reduced).

those of birds; and it is not impossible that we have here the impression of the hind foot of a huge reptile of terrestrial habits, which may have usually walked upon the hind legs. Still, as against this view, it should be noted that the tracks far more frequently consist of two than of four feet; and, although the *Deinosauria* (dreadful lizards) possessed, at least in some instances, massive hinder limbs, with comparatively slight fore legs, and were mainly terrestrial in habit, it is difficult to believe the mode of progression on two legs

habitual to them. Professor Huxley has, however, remarked that "the whole structure of the deinosaurian hind limb is exactly that of an embryonic bird." An interesting adjunct to this example is the impression of rain-drops beside the footprint.

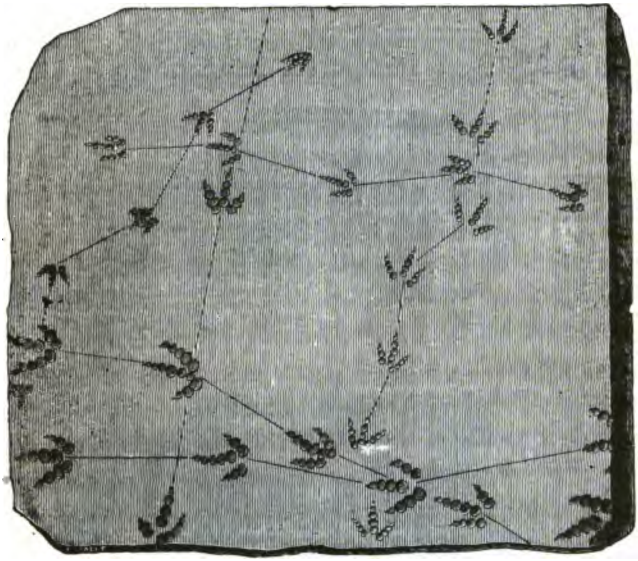

FIG. 20.—Footprints of birds (or reptiles?) in Triassic sandstones (reduced).

Important as this great accession of reptilian life is, zoologically considered, yet it would seem that the biologist who would trace the continuity of life must confess that a great chasm still remains to be bridged. The regular order of succession among vertebrate animals would be fishes, amphibians, reptiles, birds, and, finally, the lowest class of mammals. This order

has been preserved up to the advent of reptiles, but the intermediate link, the bird, is wanting; and while, so far as we know them at present, the dominant types are low in the scale, one—belonging to the mammalian class—presents itself suddenly. Among these great reptiles we should never have expected to find an example of a creature which gives suck to its young, without the intervention of the intermediate bird form.

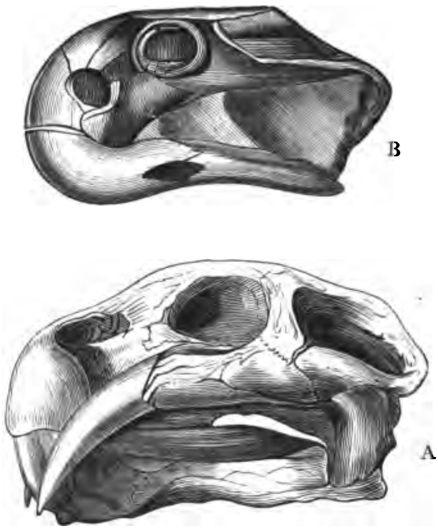

FIG. 21.—Skulls of Triassic reptiles, from South Africa. A. *Dicynodon lacerticeps*, with large canine-like teeth; B. *Oudenodon Bainii*, with beak-like jaws (reduced).

Nevertheless, here it is. In the Trias of Europe (including Britain) and North America, have been found the jaws and teeth of small insectivorous mammals, which Professor Owen has referred to the

marsupial order, the European form having been named *Microlestes antiquus*, and the American *Dromatherium sylvestre*. Lying almost at the very base of the mammalian class, and producing their young in an undeveloped condition, the marsupials also exhibit marked structural affinities with birds, which may yet be discovered in unexplored areas of the Trias.

Succeeding without interruption to the Triassic are the vast argillaceous and calcareous formations of the Jurassic, constituting a grand storehouse of the remains of large marine and terrestrial animals, the predominant types of which are reptilian, and more specialized in structure than any we have hitherto met with. No very marked change has taken place in vegetation, although the character of the conifers now approaches that of existing araucaria and pandanus, while cycads and ferns hold an important place in the flora of the time. The crinoids are represented by such beautiful forms as *Pentacrinites*; sea-urchins of various species, star-fishes, and crustacea abound. Jurassic seas and estuaries contained great beds of oyster-like bivalves, among which were *Ostrea acuminata, O. gregaria, O. deltoidea, O. Marshii, O. distorta, O. expansa,* and the various species of *Gryphœa* and *Exogyra*, the beaks of whose shells were turned inwards in the former genus and outwards in the latter, besides the singular double-beaked *Diceras*. Of the chambered cephalopods with external shells we have an immense variety, included in the genus ammonites (and the allied *Nautilus*), two beautiful examples of which are *A. Humphresianus* and

A. bifrons, while goniatites and ceratites are no longer represented. On the other hand, forms allied to modern cuttle-fishes have left their horny "pens" and ink-bags to testify to their abundance, and the chambered

FIG. 22.—*Ammonites bifrons;* a tetrabranchiate cephalopod; viewed in profile and in front (Lias). (Reduced.)

"guards" or internal skeletons of belemnites occur in vast numbers. One true shark presents itself here, together with the old forms, and a few of the fishes show a tendency to assume the equal-lobed tail.

Of insect life we have comparatively scanty evidence, but it is extremely probable that the few known spiders,

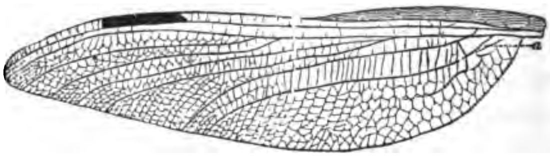

FIG. 23.—Wing of a fossil dragon-fly; from the Warwickshire Lias.

centipedes, scorpions, and locusts, are mere fragments of a rich class. The Stonesfield slates have, however, yielded one specimen of a lepidopterous insect (a

butterfly), to which the title *Palæontina oolitica* has been applied.

The Jurassic period derives its greatest importance from the abundance of its reptilian life—its *Enaliosauria* (marine reptiles), its *Deinosauria* (dreadful reptiles), and its *Ornithosauria* (bird-reptiles). Of these three orders of Mesozoic saurians there are no living representatives, neither did they extend beyond the Cretaceous period. Strictly speaking, the term "sauria" should be rendered "lizards;" but, since the forms under consideration are not necessarily allied to the lacertilian section of reptiles, it may be more convenient to include all under the wider designation of "reptiles"—bearing in mind the above reservation. In the seas inhabited by these marine monsters, which are divided into the principal genera of *Ichthyosauria* (fish-reptiles), *Plesiosauria* (a term implying characters nearly lizard-like), and *Pleiosauria* (more lizard-like), there are indications, as for example in the presence of corals, nautili, etc., of the prevalence of a warm climate favourable to the development of animal life, an abundance of which must have been necessary to support such multitudes of rapacious creatures. Apart from the nature of their teeth, always of the long, sharp, conical form, well calculated to retain an active prey, we know that the enaliosaurs were carnivorous from the remains of fishes occasionally found in the cavity occupied by the stomach, and in their fossil excrement. All the four limbs were modified into powerful swimming-paddles, with their bones enclosed

FIG. 24.—*Ichthyosaurus communis* (restored).

in one broad sheath, constituting organs perfectly adapted to rapid motion in water, and perhaps affording some facility for progression over the muddy flats of the estuaries and shallow seas in which the Lias, Kimmeridge, and Oxford clays seemed to have been deposited. The ichthyosaur differed considerably from his congener, the plesiosaur, in the size of his formidable jaw, the robustness of his body, and the length of his tail, which may possibly have been provided with lobes of muscular flesh on its upper and lower margins, to increase the animal's swimming powers. Its habitat was probably the deeper parts of the sea, where it must have proved a more relentless foe to all living creatures than existing sharks, for some specimens attained a length approaching to forty feet. The pleiosaurs possessed a similar organization, with even greater bulk, examples of their paddles six feet in length, and teeth twelve inches long, being known. Relatively lighter in frame, the plesiosaurs were the tyrants of shallow waters, in which they lurked, resting on the mud with their long necks extended, waiting for

the finny prey, or swimming near the surface among shoals of fish, and capturing them with the utmost rapidity. In these the anterior and posterior surfaces of the vertebræ are only slightly bi-concave, whereas they are deeply cupped in the ichthyosaurs; and the teeth, instead of being inserted in a common longitudinal groove, are sunk in distinct sockets, on the crocodilian

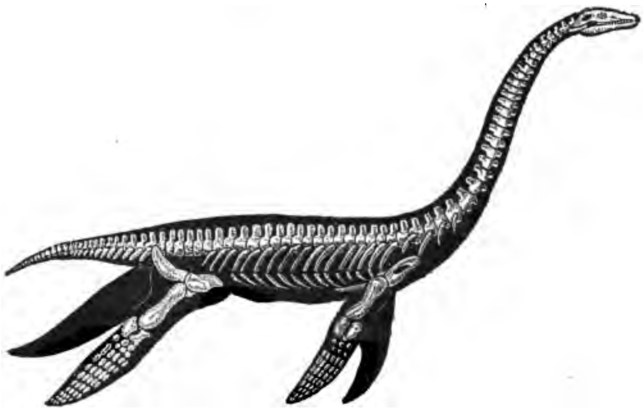

Fig. 25.—*Plesiosaurus dolichodeirus* (restored).

plan. Although, on the whole, plesiosaurs were not so well fitted for a deep-sea existence, and the general plan of their structure would render these animals less active in the water than the ichthyosaurs, their paddles are in no respect inferior as organs of aquatic locomotion, and we must regard them as sharing with their larger companions unchallenged dominion of the Oolitic ocean.

In the deinosauria we have another extraordinary group, common to both this and the succeeding period, and distributed over the New World as well as the Old.

There can be little doubt that these were mainly, if not entirely terrestrial, and chiefly carnivorous; frequenting the dense growth of ferns and cycads by the river-banks, and occasionally committing their unwieldy frames to the buoyant waters. The principal Old World genera of Jurassic deinosaurs are *Scelidosaurus* (with lizard-like leg) from the Lias of Charmouth, *Omosaurus* (with lizard-like shoulder) from the Kimmeridge clay at Swindon, *Cetiosaurus* (the whale-like reptile), and *Megalosaurus* (great reptile); and the American genera, *Camarasaurus* described by Professor Cope, and *Atlantosaurus* and *Morosaurus* discovered by Professor O. C. Marsh on the flanks of the Rocky Mountains. Their structural characters are peculiar, partaking of those belonging both to reptiles and birds, and to the latter in so considerable a degree that Professor Huxley has proposed for the order the term *Ornithoscelida* (or bird-legged). In some instances at least the hind limbs were massive, while the fore limbs were comparatively feebly developed, whence the probability of their walking upon two legs has been inferred. Professor Philips, reasoning from the structure of the "cup-and-ball" joint, which attaches the hind limb to the upper portion of the skeleton, strongly insists that the leg had a forward movement in the line of the body, indicative of an animal capable of walking very freely, and without the awkward reptilian gait. Again, Professor Owen has pointed out structural relationships with the hippopotamus and rhinoceros, and Professors Huxley and Cope trace affinities between deinosaurs and birds. The

skeleton, then, was in a transitional state, as was that of the ornithosaurs of the same period. The genus *Compsognathus*, from the Solenhofen beds, exhibits bird characters to an extent greater, perhaps, than any other of these forms, inasmuch as Professor Huxley goes so far as to say, "It is impossible to look at the conformation of this strange reptile, and to doubt that it hopped or walked in an erect or semi-erect position, after the manner of a bird, to which its long neck, slight head, and small anterior limbs must have given it an extraordinary resemblance." The teeth of megalosaurus prove its rapacious habits beyond any doubt; and cetiosaurus is conjectured by some anatomists to have been herbivorous, by others carnivorous; while all are agreed that the deinosaurs were of colossal size, attaining a length of twenty or forty feet, and, in the case of Marsh's Atlantosaurus, even eighty feet!

Three great groups of true reptiles—the crocodiles, turtles, and lizards—are well represented in the Middle and Upper Oolitic series, the most important of which are the gavial-like *Teleosaurus*, a large crocodile, and *Chelone plainceps*, a turtle found in the Portland beds.

Hitherto the dominant races of the earth have been terrestrial or marine, and, with the exception of insects, no creature organized for flight has made its appearance. We have had saurians whose hind limbs at least indicated affinities with birds, but nothing in which could be traced the semblance of that most characteristic organ—the wing. Professor Huxley has remarked, "On the whole, it is certain, from anatomical characters alone,

that birds are modifications of the same type as that on which reptiles are formed, and if this similarity of structure is the result of community of descent, we should expect to find, in the older formations, birds more like reptiles than any existing bird, and reptiles more like birds than any existing reptile. If the geological record were sufficiently extensive, and the conditions of preservation favourable, we ought to find an exact series of links; but this, of course, is hardly to be expected; and it will be a great step if we can show that certain forms tend to bridge over the gulf between the two groups." The forms here referred to first present themselves in the Jurassic period, and continue in increasing numbers throughout the Cretaceous. At first, the reptilian characters predominate, or are very strongly marked; but as we advance to later Cretaceous and finally enter Eocene times, they become fainter, and at length give place to the special features of existing birds, with but slight traces of the reptile.

The leading genus of Oolitic *Ornithosauria* is *Pterodactylus* (wing-fingered), which we may consider the type of a large group related to *Dimorphodon* (having two forms of teeth) and *Ramphorhynchus* (hook-beak). The Jurassic limestones of Solenhofen, owing to their fine texture, have preserved the remains of numerous pterodactyles in excellent condition; but these are comparatively small specimens, and do not exhibit the peculiar anatomy so well as the larger fossils of Cretaceous age. In size they range from the proportions of a pigeon to those of the albatross, but some remains

indicate an animal whose extended wings covered a space of fifteen feet, or even more. The long and powerful jaws, set with numerous crocodilian teeth implanted in distinct sockets, proclaim their predatory habits and reptilian affinities, to which the vertebral column (or backbone) conforms in some respects.

When these singular creatures were first brought to the notice of anatomists, sufficient data did not exist for determining the essential points in their structure with the degree of accuracy since attained through the investigations of Owen, Huxley, and Seeley. These osteologists have demonstrated the intimate correspondence in structure between pterodactyles and birds. Although the reptile is represented distinctly by the teeth, vertebræ, and more or less elongated tail of the pterodactyl, and by the absence of clavicles, it will be seen that the bird claims the majority of the points. In the first place, the compressed beak, the skull, and the elongated neck are more avian than reptilian. Then, as in all birds of flight, the sternum (or breast-bone) is furnished with the prominent ridge, or keel, for the attachment of the large pectoral muscles which move the wing-bones—a structure totally unrepresented in reptiles. The coracoid bones, whose function in birds is to keep the shoulders apart during vigorous motion, are highly developed in the pterodactyl, and the bones contain those pneumatic cavities peculiar to the class of birds. On these characters alone the anatomist would be justified in deciding that the animal was capable of rapid and sustained motion in air. But he has more

direct and conclusive proof than these structural homologies. The fore limb proclaims itself unequivocally an organ of flight, and particularly by its "hand." Formerly, this part of the skeleton was figured and described as similar to that of a bat, whose four greatly elongated and extended digits support a thin membrane of flight, which is continued from the end of the outer or little finger to the foot, and thence to the point of the tail. The largest and longest digit in the hand of the pterodactyl, then, was supposed to correspond to the outer digit of a reptile or bat, and the whole apparatus of flight was believed to have ulnar attachment. This, if true, would tend to remove the pterodactyl from the class of birds. The researches of Professor H. G. Seeley, however, have placed the anatomy in a new aspect. In birds the radial part of the fore-arm gives attachment to the *index metacarpus* (corresponding to the palm bone of the fore-finger in man), which carries the principal feathers of the wing known as the "primaries," while the ulnar portion gives rise to a bone representing the outer members of the human palm. By comparison of numerous specimens, Professor Seeley arrives at the conclusion that this was the plan of articulation in the ornithosaurian fore limb; that the index finger supported the membrane of flight, the remaining three outer digits being free and terminated by claws; and that, in fact, the fore-arm, with its dependent bones, was, in all its main features, the limb of a bird. The bone, corresponding to our first finger, with its phalanges or smaller joints, was elongated to an immense extent

(about the length of the whole body), and employed in spreading the membrane attached to it and prolonged to the many-jointed, and occasionally long reptilian tail. The skeleton, then, alone afforded the most conclusive evidence of a flying animal; but this is placed beyond all question by specimens of pterodactyles in the museum at Haarlem, showing the impression of the wrinkled and folded membrane on the fine-grained stone, which was, doubtless, a soft mud when the animal became imbedded in it. The figure in the frontispiece is that of a Jurassic pterodactyl, *Pterodactylus longirostris*, restored from the fossil remains, the fore limb and foot being drawn in agreement with the now known structure of those parts, and Fig. 26 represents another of the strange ornithosaurian forms from the lithographic limestones of Solenhofen—*Archæopteryx* (ancient wing), now in the British Museum.

The limestones of Solenhofen are used for the highest class of lithographic engraving, on account of the fine surface they are capable of taking—a quality which has proved invaluable to the palæontologist. Originally fine calcareous mud, the stone is now extremely compact, and has admirably preserved the remains of this extraordinary creature, the first of all living beings clothed with feathers. In addition to a number of bones which indicate a bird as large as a crow, impressions of the shafts, webs, and barbs of the large flight feathers of the wing are traced on the stone, with as much distinctness as if they had been actually lithographed. Here and there the feathers are ruffled.

From the end of the wing-bone projected two free claws; the legs were long and terminated by four strong toes, three turned forward and one backward, as is usual with perching birds. To the long reptilian tail, composed of some twenty joints, were attached a number of broad feathers arranged in pairs opposite to each other. The tail thus has the appearance of a single feather, the bones representing the shaft and the feathers the barbs. The head is unfortunately absent, so that it is vain to speculate on the question whether it carried a

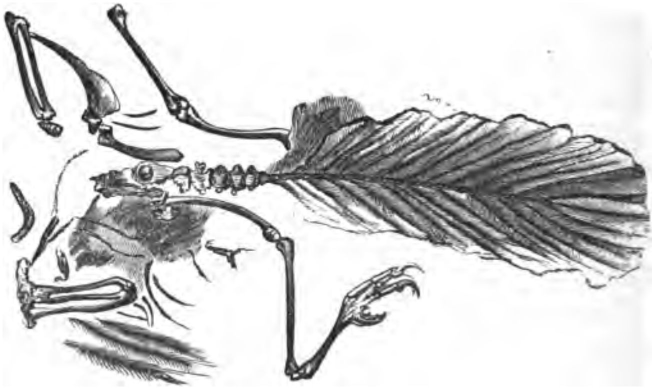

FIG. 26.—*Archæopteryx macrura.*

horny, bird-like beak or toothed jaws similar to the pterodactyl, although some authorities consider it probable that small teeth were present. A second specimen, not yet described, has been found in the Solenhofen quarries, and was offered to the trustees of the British Museum for the large sum of £2000; but it was not acquired.

Were these creatures warm-blooded or cold-blooded?

Since all existing birds are warm-blooded, and their temperature higher than that of any other animals, we may reasonably conclude that the feathered archæopteryx at all events was similarly constituted. The pterodactyles must also have undergone great exertion in their aerial life, demanding a large supply of oxygenated blood to the tissues and to repair the waste attending so active an existence. It is difficult to conceive how this prolonged effort could have been sustained by the sluggish respiration and circulation of a reptile —the most imperfect apparatus in any air-breathing vertebrate. The pneumatic cavities in the bones of birds subserve the purpose, among other functions, of aerating the blood, and are associated with a heart of the most perfect structure. If, then, we may rely upon analogy, the perforated bones of the pterodactyl would communicate with a bird-like heart; and identical characters of respiration and circulation, and an oviparous reproductive system might be assigned to it without any improbability.

The present Australian land surface is considered to be in some sense a geological survival, on account of the very considerable resemblance between its existing animals and plants and those which occupied a prominent place in other geographical areas during Jurassic times. In Australia we still have arborescent, coniferous, and cycadaceous plants, similar in character to Jurassic forms; and some molluscs belonging to this period are now represented only there. The Australian sharks are of the same type, *Cestracion*, bearing the

spine in front of the fin, and having flattened teeth for crushing shell-fish, as have many of the Oolitic fishes. But the resemblance is carried even further by the presence, in the Jurassic period, of several genera of small animals, all of the marsupial order, which is the predominant and almost exclusive group of Australian mammals. Here, in the Purbeck and Stonesfield beds of Britain we have *Phascolotherium*, *Amphitherium*, *Amphilestes*, *Spalacotherium*, *Triconodon*, *Galestes*, and *Pla-*

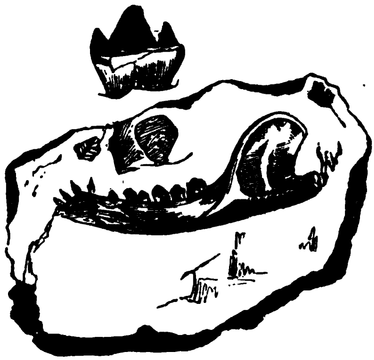

FIG. 27.—*Phascolotherium Bucklandi.* Right side of lower jaw of a small marsupial (actual size), with magnified molar tooth; from the Stonesfield slaty limestones.

giaulax, etc.; and one American genus, to which Professor Marsh gives the name of *Dryolestes*—altogether numbering some twelve species. The majority of these were probably arboreal and insectivorous, like many of the existing Australian species, and Professor Marsh considers *Dryolestes* to have been allied to the only living marsupial genus on the American continent, *Didelphys*. Some bones from the Stonesfield slate, described by

Professor Seeley, indicate an animal with resemblances inclining towards the lower order of monotremes, exemplified in the singular Australian *Platypus*. According to Professor Owen, one obscure form from the same strata, *Stereognathus*, may belong to the division of hoofed quadrupeds, in which case the higher mammals would be entitled to be included in this period.

Professor Owen has made some interesting observations on the relations between these small mammals and the diminutive Purbeck crocodiles—such as *Theriosuchus*, not exceeding eighteen inches in length—which lead him to the conclusion that they did not, like existing crocodiles, possess the valvular apparatus for excluding water from the air passages while drowning their victims; but that their fore limbs point to an activity on land which would enable them to capture and destroy the little marsupials without difficulty.

The Cretaceous was eminently a marine period. This fact may be deduced with certainty from the vast sedimentary accumulations of greensands, gault, clays, and chalks, and the marked preponderance of marine fossils. That it is the immediate successor of the Jurassic, too, is proved by the existence of enaliosaurs and ornithosaurs common to both; but the new forms of plants and animals exhibit far more advanced characters. The plants, at least of the upper strata, in regions so widely separated as Europe and America, include forms botanically similar to the oak, beech, poplar, plane, alder, willow, cypress, fig, magnolia, etc., and, for the first time in the earth's history, *true* palms—almost

entirely usurping the place of the cryptogams which had held possession of the land since Devonian times. So little, comparatively, remains of the Cretaceous land, that the record of its fauna and flora must necessarily be very imperfect; but what is left in the form of thick beds of coal and lignite is quite sufficient indication of a rich vegetation in certain areas, particularly in Vancouver Island, whose splendid coal-field is assigned by Professor Dawson to this period.

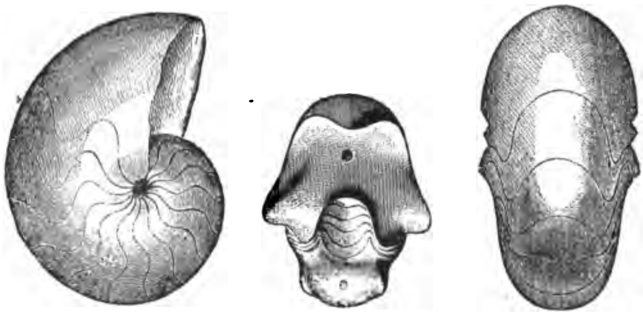

FIG. 28.—*Nautilus Danicus* (in different positions); Upper Cretaceous.

No more than passing mention can be made of the varied lower forms of life which inhabited the ocean. The shells of foraminifers belonging to genera still found in the Atlantic, constitute almost the whole substance of some chalks, and glauconite casts of them abound in the greensands. Sponges frequently completely silicified, corals, sea-urchins, and mollusca occur in great variety. The ammonites are now of huge size two or three feet in diameter—but, like the numerous belemnites, have not been recognized in any subsequent

period. The old orders of fishes remain, and have now reached gigantic proportions, if the sharks may be judged by teeth three or four inches in length; but it is important to notice the first appearance of the

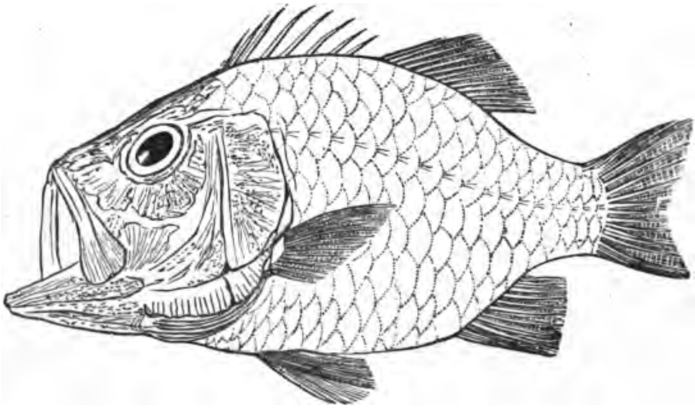

FIG. 29.—*Beryx;* a percoid fish from the chalk.

highest orders—representatives of the perch, salmon, and herring families, with homocercal (or equal-lobed) tails, a bony skeleton, and horny, overlapping scales.

No amphibians are at present known, nor any remains which can be referred with certainty to the mammalian class; but the MESOZOIC era retains its character as the "Age of Reptiles" to the very last. The plesiosaurs and ichthyosaurs survive; the pterodactyles assume a monstrous size; the deinosaurs are represented by the old form megalosaurus, to which are added the new European genera *Iguanodon* and *Hylæosaurus*, and the American *Hadrosaurus* and *Lælaps*,

all of vast bulk, and probably carnivorous. Impressions of three-toed feet in the strata, where bones of iguanadon are found, tend to strengthen the inference deduced from the Triassic footprints, that some of the deinosaurs walked upon two legs, placing one foot before the other, like birds. Besides some small reptiles of undoubted lacertilian form, crocodiles closely related to existing species, and true fresh-water and marine turtles, there is another class of reptiles, whose affinities are not so clearly defined, of which several species have been recognized in the Maestricht chalk on the river Meuse, whence they have received the generic name *Mosasaurus* (lizards of the Meuse). They appear to have had all the limbs modified into paddles, resembling those of cetaceans, and one species rivalled any of the marine monsters in length.

In the ornithosaurian class, the approach to true birds becomes most striking and interesting, and strongly confirmative of the principles of descent foreshadowed in the early Jurassic pterodactyles. The American continent supplies these important links in the chain of affinities between reptiles and birds. Professor Marsh's description of the new genus, *Pteranodon* (implying a winged but toothless animal), leaves no doubt that this was a form intermediate between the pterodactyles and birds, in that it was destitute of teeth, and the jaws must, therefore, have had the character of a beak; while it retained the general structure and powers of flight of the pterodactyl. Another step towards the bird is taken by a huge penguin-like creature, named by

Professor Marsh *Hesperornis* (western bird), from whose skeleton its relationships with true birds can be determined precisely. The breast-bone without a "keel," the strong, short legs, and feet probably palmated or webbed, and the entirely aborted wings place it among those birds which depend upon their powers of swim-

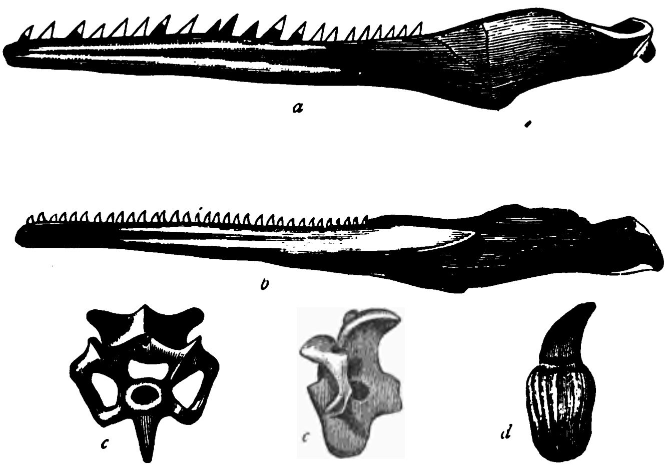

FIG. 30.—Cretaceous birds (America): *a.* lower jaw, left side, of *Ichthyornis dispar* (slightly enlarged); *b.* lower jaw, left side, of *Hesperornis regalis* (about one-fourth actual size); *c. c.* cervical vertebræ of *Ichthyornis*, front and side view; *d.* tooth of *Hesperornis* (twice actual size).

ming and diving for capturing their prey, with the further addition of sharp, recurved teeth in both jaws. When standing upright, it must have equalled the height of an ordinary man. One more form, *Ichthyornis* (fish-bird), completes the series of American Cretaceous avi-fauna, and furnishes yet another link in this wonderful chain.

Here we have again the reptilian teeth, small though they are, implanted in separate sockets, and vertebræ hollowed out at both ends—the teeth and backbone of a reptile or fish. But the principal organ, that of flight, was the wing of a bird, and we can have no reasonable doubt that its possessor was covered with feathers, and led a predatory life among the denizens of the water or air, perhaps now dashing down upon a fish, and again hawking at some of the winged insects, which it is not easy to believe the forests of oak, beech, etc., and the willow-fringed streams did not bring forth abundantly, though we have not yet discovered any of them. The size of ichthyornis, about that of a pigeon apparently, would at all events have restricted its predatory operations to a smaller class of animals than would suffice for its gigantic contemporaries, pteranodon and pterodactylus. Prior to the discovery of these American forms, however, Professor Seeley had described the genus *Enaliornis* (sea-bird), from the Cambridge upper greensand, another relative of the penguins and divers, one species of which at least resembles ichthyornis in its bi-concave vertebræ.

On a general view of the MESOZOIC fauna and flora, it is impossible to resist the conclusion that the climate of the whole earth was very much warmer in high latitudes than it is now. Corals abounded in seas whose present temperature would be fatal to them. Coal-forming plants grew far within the Arctic area, where mosses and lichens alone can now exist, and in sufficient luxuriance to create thick deposits. Ammonites lived in the seas of Alaska and Greenland, and the ichthyo-

saurus in Spitzbergen and Exmouth Island. Animal and plant life has now reached a high stage of development. The lowly orders of flowerless plants have been succeeded by stately trees, and, instead of holding sole dominion of the soil, they are passing into the insignificant position they occupy at this moment as survivals—dwarfed and feeble descendants of a once powerful family. We have seen the lowest forms of marine life rise, as it appears to us, from the Laurentian eozoön to the Cretaceous fishes. The PALÆOZOIC era, abounding in its extinct trilobites and amphibians, knew no warm-blooded animals, few reptiles, and none of the higher types of life, the bird-like creatures and mammals of the later MESOZOIC. Among the fish-reptiles and bird-reptiles are displayed structural affinities with types both below and above them in the zoological scale, more remarkable than anything presented to us in the early stages. The primitive pterodactyl passes out of existence with the Cretaceous period, but the bird type survives in other shapes, losing in the direction of the reptile and gaining in that of the bird, until, after the great physical break which intervenes between the Upper SECONDARY and Lower TERTIARY, the fossil bird passes almost completely into the existing form.

FIG. 31.—Section of chalk (highly magnified).

Whether this succession in point of time is to be considered intimately bound up with continuity of life and the descent of higher from lower organisms, or is that which philosophy refuses to recognize—an accidental circumstance—every ingenuous mind must be deeply impressed with a feeling of astonishment that each period in the history of our globe should afford examples of structures which are embryonic in a given class during one period, and fully developed in the succeeding, whilst the rule throughout all classes of the animal kingdom has been progression towards a more specialized structure, with the exception of a few lowly creatures, in which the primordial form has persisted throughout all ages and been handed down to us scarcely modified.

TABULAR VIEW OF THE MESOZOIC SYSTEM OF ROCKS, WITH THEIR PREVAILING OR CHARACTERISTIC FORMS OF LIFE.

MESOZOIC, or SECONDARY.	CRETACEOUS.	Well represented in Europe and North America. Clays, sands, soft limestones, and lignites. Maestricht beds, chalk with and without flints, upper greensands, gault clay, lower greensands (or Neocomian), Wealden clay. Plants of the higher orders—oak, beech, willow, poplar, alder, cypress, etc. Foraminifers and echini abundant. Ammonites of immense size. Bony fishes of the salmon, herring, and perch families first appear; with gigantic sharks. Reptiles—ichthyosaurs and plesiosaurs—abundant; a new form, *Mosasaurus*. Crocodiles and turtles. New deinosaurs—*Hylæosaurus*, *Hadrosaurus*, *Lœlaps*, *Iguanodon*. Pterodactyles gigantic—new genus, *Pteranodon*. New bird-reptiles—the American genera, *Ichthyornis* and *Hesperornis*, and the British *Enaliornis*.
	JURASSIC, or OOLITIC.	Well developed in Europe and India; occur also in North and South America, Australia, and the Arctic regions. Consist of, principally, Limestones, Coral rags, Clays, and Marls, with some Coal. Purbeck and Portland beds, Kimmeridge and Oxford clays, Upper and Lower Oolites, fuller's earth, Upper and Lower Lias. Plants similar to Triassic. Decapod crustacea abundant. Insects numerous. The first fossil butterfly. Oyster forms abundant, *e.g.* *Gryphæa*. Ammonites, *e.g.* *A. Humphresianus* and *A. bifrons*. Fishes of *Placoid* and *Ganoid* orders. Marine reptiles—*Ichthyosaurus*, *Pleiosaurus*, and *Plesiosaurus*, Crocodilian, Lacertilian, and Chelonian reptiles. *Deinosauria*—*Megalosaurus*, *Atlantosaurus*, and *Cetiosaurus*. First appearance of *Ornithosauria* (bird-reptiles), *Pterodactylus*, *Ramphorhynchus*, and *Archæopteryx*. Mammals represented in both hemispheres, by several species of marsupials.
	TRIASSIC.	Principal development in Germany. Consist of Sandstones, Limestones, and Clays. Rhætic and Dachstein beds, Muschelkalk, and Bunter-sandstein, with salt. Some coal measure plants disappear. Cycads and Conifers abundant. *Belemnites* first appear. True *Ammonites* first appear. Amphibia represented by *Labyrinthodon*. Reptiles abundant, represented by the lacertilian forms, *Hyperodapedon* and *Telerpeton*; and the doubtful forms, *Dicynodon*, *Oudenodon*, *Cynodraco*, *Placodus*, *Belodon*, *Limosaurus*, *Rhynchosaurus*, *Nothosaurus*, etc. Fossil footprints of gigantic reptiles (or birds). First appearance of mammals—small marsupials—*Microlestes* and *Dromatherium*.

THE KAINOZOIC ERA.

CHAPTER XI.

THE EOCENE AND MEIOCENE LIFE-PERIODS.

Origin of the TERTIARY formations—Eocene climate and sub-tropical vegetation — Fossil forests — Nummulites. Extinction of some molluscs. Fishes — Reptiles — Serpents, cetacea — *Deinocerata*—*Palæotheria* — Equine forms — Marsupials—Bats—Carnivora (?)—Birds—Tropical character of Meiocene flora in northern latitudes—Cetacea, tortoises, and insects—Carnivora, rodents—The "sabre-toothed" lion—Giraffes, camels, sloths, bats, apes—Large herbivorous animals, *Brontotherium*, *Titanotherium*, *Deinotherium*, *Sivatherium*, *Mastodon*, rhinoceros, and hippopotamus.

THE formations of the TERTIARY era owe their origin in a very great measure, no doubt, to disintegration of earlier rocks, and particularly those of Cretaceous age. So greatly has denudation affected these latter, that in some very large areas there is no conformability whatever between their strata and the Eocene beds. Chalk flints, usually much water-worn, constitute immense deposits of gravel, and a few characteristic Cretaceous fossils are distributed amongst the new formations. Thus a

sharp line has been drawn, behind which lie many once predominant forms—such as the enaliosaurs, plesiosaurs, pterodactyles, belemnites, ammonites, etc.—and the survivals are few and unimportant. On the Eocene side of the line, however, numbers of new genera have come into existence, the approximation towards existing types becomes progressively closer, and the proportion of species related to extinct types decreases, while the proportion of those allied with living forms increases very rapidly throughout the TERTIARY era. In America, the break between the SECONDARY and TERTIARY eras does not appear to be considerable; indeed, in certain localities, the rocks are entirely conformable, and we may therefore hope to find there some connecting links between the Cretaceous and Eocene life—forms which have been lost in the European area—a hope much strengthened by the recent discoveries of Marsh and Cope.

In Early and Middle TERTIARY times, at all events, the temperature of the Northern hemisphere must have been much higher than at present. European rocks of this era have yielded representatives of the American sequoia, taxodium, robinia, etc.; of the Asiatic planes, cinnamons, etc.; and of the Australian eucalyptus, Banksia, etc. In Spitzbergen Meiocene beds we have the taxodium, pine, poplar, willow, elm, etc., and a water-lily; besides considerable deposits of coal in Grinnell Land, beyond the eighty-first degree of north latitude. In the estuarine waters which deposited the London clay, lived species of large nautilus, together with corals and

other witnesses to a temperature probably averaging 15° Fahr. higher than in our time.

The co-existence in Europe of exotic flora with those characteristic of temperate regions, suggests a continuity of land surfaces over which the plants migrated, for their abundance and excellent preservation indicate that they grew *in situ*, and were not brought by ocean currents from distant lands and accidentally cast ashore. The seeds might doubtless have been so transported; but they could not have established themselves had they not found a genial climate, and it is impossible to entertain the idea that leaves could have been carried any distance and still have retained all their delicacy of structure. Among many instances of this may be mentioned the collection of thousands of leaves of spice plants, palms, taxodium, and other exotics, from the Eocene sands and clays of South Hampshire, by Mr. J. Starkie Gardner, which frequently exhibit the minutest details of the original venation and woody fibres.

Among the interesting objects brought to light by the United States Geological Survey, none surpass the fossil TERTIARY forests of the Yellowstone region. Trunks of trees are found here on the banks of the Yellowstone river, standing upright in rows one above the other, from the top to the bottom of the cliffs, like the columns of a temple. These splendid silicified trunks, from twenty to thirty feet in height, rivalled their mighty descendants, the Wellingtonias, in bulk. Forest stands piled upon forest through strata 4000 feet thick, which must have

been the result of many alternations of sea and land occupying a vast period.

The general aspect of the Tertiary flora leads to the conclusion that the existing vegetation of the globe has descended directly from botanical types which, for the most part, appeared first during this era in any considerable force, although some were distinctly foreshadowed in the Later Secondary.

A striking feature of the Eocene period is the inconceivable abundance of such low forms of life as the foraminifers. Certain members of this group, the nummulites—coin-shaped shells, about an inch in diameter—constitute a large portion of the mountain systems of the

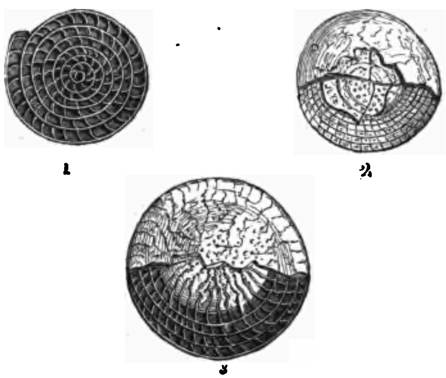

Fig. 32.—*Nummulites;* from the stones of which the Great Pyramid is built (actual size). No. 1. a section of the shell, showing the internal chambers; Nos. 2 and 3. with part of the surface layer removed.

Old World—the Alps, Pyrenees, Carpathians, the Atlas and its spurs, and the great chain which passes through Northern Persia, Hindustan, and Tibet—an area alto-

gether of vast extent. And this stupendous formation, rising at some points more than 16,000 feet above the level of the sea, is the work of a marine shell-fish—calcareous matter deposited by a lowly foraminifer at the bottom of an Eocene ocean, and subsequently raised to the position it has maintained until this day.

Not to dwell upon the numerous mollusca of the period, it may be sufficient to observe that they are still approaching more closely to existing forms; while the ammonites, belemnites, and hippurites are extinct, and never again appear in any strata of *undoubted* TERTIARY age. The nautilus, on the other hand, is represented in the Eocene clay of London by the three large and beautiful species, *N. imperialis*, *N. regalis*, and *N. urbanus*, many of which have been found during the progress of engineering works—such as the tunnels of the Midland and London and North-Western Railways through the clay lying on the southern flank of Hampstead Heath, and in various well-borings. In these specimens, the nacre retains much of its delicate iridescent hue.

Judged by their teeth—three or four inches in length—the sharks are of huge size. Both the bony and cartilaginous fishes abound, and perhaps nearly one-half of them belong to existing genera—including the very characteristic *Pleuronectidæ*, or turbots, soles, etc. Among reptiles, there are several species of turtles, tortoises, and lizards; and it is a noteworthy fact that forms, so widely separated geographically as the American alligators and the Indian gavials, should have inhabited the same waters in the south-west of England

together with the typical crocodiles. If, as there is every reason to suppose, the Mesozoic marine saurians became extinct before the deposition of the Eocene strata, it may be said that reptilian life had assumed quite a modern character in Early Kainozoic times; for the isolated occurrences of remains of ichthyosaurs in London clay and Eocene beds in Malta cannot be accepted as evidence of their contemporaneity with these formations. Professor Seeley, with other distinguished palæontologists, regards them as having been derived from disintegrated Lias. But if the enaliosaurs have passed away, we have in their stead a gigantic cetacean, the *Zeuglodon* (yoke-like tooth), allied to some existing whales, and, consequently, a marine mammal, associated with the *Halitherium*, a representative of the aquatic order *Sirenia*, herbivorous mammals, like the manatee and dugong.

One important addition is now made to the reptiles, which again incidentally points to the sub-tropical nature of the European climate in this life-period. In the temperate regions of the earth, all the serpents are small, the largest existing English species measuring only about three feet; but the African, American, and Asiatic constrictors attain large dimensions—almost rivalled, however, by the python-like snakes found in the Eocene deposits of both the south of England and the United States.

The deinosaurs are now replaced by a singular group of quadrupeds, restricted to the Rocky Mountain region, Professor Marsh's order *Deinocerata* (with terrible horns),

whose peculiarity was the possession of two very large canine teeth in the upper jaw, and a small pair in the lower, with six small molars on each side behind them, and three, or at least two, pairs of horns, of which the first pair were placed on the nasal-bones, the second further

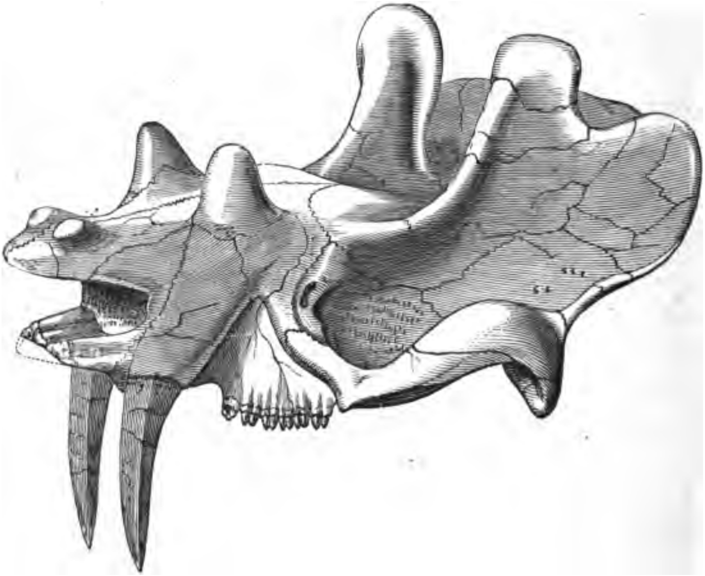

FIG. 33.—*Deinoceras mirabilis;* from the Eocene of Wyoming, America.

back on the jaw, and the third over the frontal portion of the cranium, as indicated by the prominent "cores" for their attachment to the skull, whence also it may be inferred that these weapons were similar to those of the ox and other hollow-horned ruminants. Here we have an animal of composite structure, with elephantine limbs

and five-toed feet, the head studded with horns of the bovine type, and tusk-like teeth proclaiming its carnivorous habits; while its massive cranium held an exceedingly small brain, whose diameter was in no part greater than that of the spinal cord—such as we might expect to find in an amphibian or reptile. The order *Tillodontia* also combined the characters of ungulates, rodents, and carnivores.

The Eocene period, indeed, is remarkable for its great wealth of mammals (in singular contrast to the barren Cretaceous) which osteologists do not hesitate to recognize as the ancestors of the existing horse and tapir. First we have the *Palæotheria* (ancient beasts) of several species, varying greatly in size up to that of a small horse. Cuvier's description and figure of the animal gave it the form and proportions of the tapir; but the excellently preserved complete specimen found in the gypsum quarries at Vitry-sur-Seine, in 1873, renders modification of his restoration necessary, although his reference to it as an ally of the tapirs is confirmed. *Palæotherium magnum* was an elegant animal, apparently resembling the llama in general appearance, of gregarious habits, and very numerous in France; and it almost certainly had the upper lip prolonged into a short proboscis, comparable with that of the tapirs.

Another very interesting series of herbivorous quadrupeds lies structurally in the line of the modern equine group. These are the genera *Orohippus*, *Anchitherium*, and *Hipparion*, whose feet approach, in the order given, to the simple form of the horse's. The toes in all were

hoofed, and in all the middle was the largest and longest. In the first case, there were on the fore legs four toes touching the ground; in the second, three (the outer member having disappeared); and in the third, still three, two of which were simply useless appendages hanging freely from the limb on each side of the principal member. By these gradations, the suppression of the outer toes, the foot of the horse, with its accompanying "splint" bones, the aborted second and fourth digits, is reached. In the Meiocene and Pleiocene formations of America are other polydactylic mammals leading up to the horse. Thus *Mesohippus* possessed three functional toes and a splint-bone on the fore feet, with three toes on the hind feet; in *Miohippus*, the splint-bone was still further reduced; and *Pliohippus* had but one functional toe on each foot; while on the immediately succeeding geological horizon the true American horse makes its appearance. The evolutionist bids us take particular note of this remarkable series, because it forms one of the strongest bulwarks of the derivative hypothesis. He points to these forms of ungulate animals, all preceding the horse in time, none but hipparion (and this the most nearly approaching him in structure) surviving until the true horse appears; and asks us to consider whether there is not the strongest probability that the series represents a line of descent, branching off at some remote period towards the camels, giraffe, rhinoceros, etc. As an evolutionist, Professor Huxley says that the case of the horse is one which "will stand rigorous criticism."

Added to the above mammalian types, the marsupials

take a more distinct place than heretofore; for, besides other leading genera, the neighbourhood of Paris produces an opossum, *Didelphys gypsorum*, closely akin to its existing American congeners. As yet no true swine have appeared, but *Hyopotamus*, *Anoplotherium*, and *Chœropotamus* share both their characters and those of ruminants, while neither the hippopotamus nor rhinoceros was known to Eocene times. Among carnivora, we have *Hyænodon* (with hyæna-like teeth), and two small animals allied to the racoon and dog; but the latter rests on the very doubtful evidence of a single tooth from the Paris gypsum, which, however, affords a good specimen of a bat similar to existing species.

Whatever doubt may attach to the fragmentary evidence for the existence of an Eocene monkey in the European area, subsequently so well attested in the Meiocene strata, the class of birds holds a very prominent place in the period we are considering, both in Europe and America. From the general characteristics of these fossils, it would seem that they are prototypes of our natatorial, cursorial, insessorial, scansorial, and raptorial birds, embracing five principal orders. The ostriches and emus are represented by the Parisian *Gastornis*, and by *Lithornis emuinus* and *Dasornis Londinensis* from the Sheppey clay; and an immense bird of flight, related to but far larger than the albatross, described by Professor Owen under the name of *Argillornis longipennis*, also frequented the great estuarine region of Eocene times now occupied by the London basin. Fortunately, in one case, the skull of a London clay bird has been

preserved, and from this we know that sharp, conical, bony processes sprang from the edges of both jaws, and were continuous with the bone itself, comparable, but in a greatly exaggerated degree, to the serrations on the beaks of some living aquatic birds.* This, according to Professor Owen, who names it *Odontopteryx*, was a natatorial bird, endowed with powers of flight, and a fish-eater.

The great marine and fresh-water lacustrine formations of Meiocene age, and the extensive accumulations of lignite, supply us with abundant information on the character of its animals and plants. In Continental

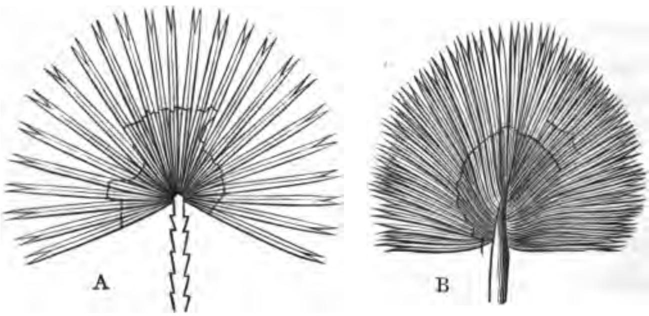

FIG. 34.—Meiocene palms (France and Switzerland): A. *Chamærops Helvetica*; B. *Sabal major*.

Europe, India, North America, and the Arctic regions, the strata are often of considerable extent and thickness, but seem to have been sparsely deposited in Britain,

* Besides the epidermal imitations of teeth in existing natatorial birds, one living South American perching bird, *Phytotoma rara*, has teeth ossified from the jaws.

a few patches only occurring in Devonshire, the Isle of Wight, and, possibly, in the Island of Mull. Now, with regard to some of these beds, there is not complete unanimity of opinion as to their precise age—*i.e.* whether they should be classed with Late Eocene or Early Meiocene strata, but they will be ranked here provisionally as Meiocene.

As in Eocene times, the climate of the Northern hemisphere was sub-tropical. This is clearly made out by the plant remains, which, in addition to European types, include an abundance of American, African, Asiatic, and even Australian forms. Continental Europe produced fan-palms, Banksias, sarsaparillas, tulip trees, cinnamons, etc. In Devonshire flourished vines, figs, cinnamons, and a member of the sequoias. Greenland possessed a mean temperature at least 30° Fahr. higher than at present, for there, among broad-leaved limes, maples, and planes, flourished the evergreen magnolia, with its beautiful fragrant blossoms. Professor O. Heer's determination of the collection, made during the latest British Arctic Expedition by Captain H. W. Fielden, shows that of the Meiocene Arctic plants many species are common to Grinnell Land, Spitzbergen, and Greenland; six species being also common to European, four to American, and four to Asiatic strata of the same age; but the collection, made under such difficult conditions, cannot possibly represent, and probably understates the true proportion. Referring to the Grinnell Land flora, Professor Heer says: "These trees and shrubs, doubtless, lived on the land, and covered the

plains and hills of this far northern region with green; but that there also existed stagnant water is shown by a water-lily (*Nymphæa Arctica*), of which the rhizoma, exactly agreeing with one from the ice fjord, Spitzbergen, was found. The thick lignite-bed of Grinnell Land would indicate a large peat-moss, in which most probably a small lake existed. On the shallow bottom of this lake the great rhizomes of the water-lilies might spread, and from them the leaves would rise to the surface of the water." From the community of American, Arctic, and European plants, it would seem highly probable that, during the middle of the TERTIARY era, a continuous land surface extended in northern latitudes between the Eastern and Western hemispheres—a supposition strengthened further by the fact that species of rhinoceros were common to India and North America in Meiocene times, and that the elephantine mastodon occurs in deposits of Pleiocene age in America and Europe.

The determination of the Arctic flora just referred to as of Meiocene age has been questioned by Mr. J. S. Gardner, Professor Dawson, Baron von Ettinghausen, and others, on the ground that strata reputed to be Meiocene often lie immediately upon undoubted Cretaceous beds, and should therefore be ranked as Eocene —an objection which, in addition to others of a technical character, does not, however, invalidate the general conclusions drawn above with respect to the distribution of land and climatic influences during the TERTIARY era.

This splendid Meiocene vegetation did not flourish

and die untouched by browsing animals, as we have every reason to conclude to have been the case with the Carboniferous forests; but supported a host of huge herbivorous mammals, prototypes of the elephant, rhinoceros, hippopotamus, horse, deer, camel, giraffe, tapir, sloth, swine, etc., which in their turn were preyed upon by the most formidable feline monsters. The seas were also rich in the higher forms of life, the true whalebone whales, and dolphins, besides the old genera zeuglodon and halitherium, with sharks and bony fishes, and marine crustaceans of several existing orders. Foraminifers and molluscs abound, and bear a larger proportion than ever to modern types, and, curiously enough, the red form of coral is presented for the first time. The gigantic salamander-like amphibian, *Andrias schenchzeri*, at one time celebrated in the early annals of palæontology as the skeleton of "a man who had witnessed the Deluge" (!), was referred by Cuvier to its proper zoological place, which could not for a moment have been doubtful had any knowledge of comparative anatomy obtained in the first quarter of the eighteenth century. The most remarkable of the new reptiles is the Indian land-tortoise *Colossochelys Atlas*, which, according to Dr. Falconer, measured twenty feet in length and seven feet in height—possibly an ancient form of the group which still survives in the Galapagos, and one of the Mascarene Islands, contemporaries of the dodo and solitaire, and rapidly becoming extinct.

Insect life, representing the beetles, dragon-flies, white ants, ants, grasshoppers, day-flies, wood-bugs, and

butterflies, was never before so varied and abundant; and no region in the world seems to have been richer in them than the Rocky Mountains.

Birds no longer present the aberrant forms of past ages, but, though differing in species, are referable to leading living orders.

Among the smaller terrestrial carnivora were civet

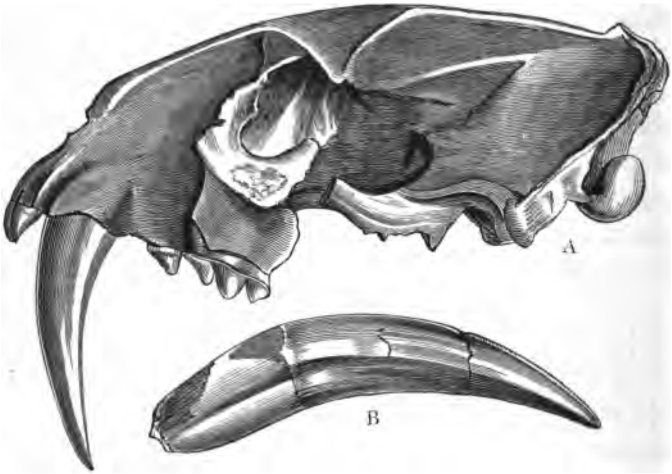

FIG. 35.—*Machairodus cultridens*: A. skull and upper jaw; B. canine tooth, one-half the actual size.

cats, otters, and weasels, and the insectivorous bats, hedge-hogs, and moles, with rodents—such as squirrels, beavers, mice, rabbits, and porcupines; but by far the most important of the predatory animals was the sabre-toothed lion or tiger, *Machairodus* (sword-tooth), whose immense compressed, blade-like upper canine

teeth, unequalled in any existing feline species, and from four to six inches long, suggest the power of encountering and overcoming any of its contemporaries.

The aspect of terrestrial life in the European area was distinctly tropical. The African giraffe inhabited Greece, the gigantic sloth-like *Macrotherium* the south of France, and the "anthropoid" or man-like apes are also represented in France by *Dryopithecus*, a monkey as large as the gorilla, together with other quadrumana allied to existing American types; and the great proboscideans had their representatives in the elephantine group to which the mastodon and deinotherium belong. The New World produced large herbivora corresponding to those of the Old World. Besides the rhinoceros of North America, we have the genera *Brontotherium* and *Titanotherium*, described by Professor Marsh as elephantine in size, and distinguished by a pair of large hollow horns on the nasal-bones, and a short trunk, similar to that of the tapir, by which the food was conveyed to the mouth.

In the Asiatic area, the Siwâlik Hills of the north-west provinces of India teem with examples of Meiocene life. Here is found the hippopotamus, now exclusively African, which differed from the living form only in having six instead of four incisor teeth in each jaw; and a species of rhinoceros. Of massive build, and in many respects totally unlike an antelope, the *Sivatherium* (from the Indian deity, Siva), has, nevertheless, been referred to that group. The head was adorned by two pairs of horns—one pair being situated over

the orbits, and a very much larger and heavier pair, reflected backwards, on the hinder part of the skull.

Conspicuous above all Middle and Later TERTIARY mammals, are the ancient prototypes of the elephant—the mastodon and mammoth—and the allied, but aberrant deinotherium. None of these is known to have existed until Meiocene times, and one, the mammoth, survived certainly in France and probably in Britain, to the human period. They were fully as large as, if not larger than the living African and Asiatic species, and differed from them in the enormous size of their tusks. Moreover, the mastodon was altogether peculiar in its dentition. It had the two upper incisor teeth prolonged into tusks in the usual way, and the two lower similarly developed, at least in early life, though they seem to have fallen out when the animal reached maturity. The molars bore on their upper surfaces conical protuberances (nipple-like), whence the generic name, by which they are at once distinguished from any other living or extinct elephant. In all other species of extinct *Elephas*, the molars have more or less flattened surfaces, with ridges of enamel, resembling those of the African and Asiatic species still existing. The Meiocene deposits of the Siwâlik Hills include more than one species of mastodon, and the European area presents an example. These same hills, as well as the Epplesheim deposits, have yielded the remains of a most singular herbivorous quadruped, the *Deinotherium* (or terrible beast), whose molar teeth possessed conical crowns similar to the mastodon's; but no tusks existed

in the upper jaw. The front of the lower jaw was, however, considerably prolonged, bent downwards, and armed with a pair of short tusks curved downwards, to which it is very difficult to assign any use, unless they were employed in digging among the soft mud of a river to obtain the roots of aquatic plants and similar food; for there is nothing to militate against the probability that the creature's habit was to frequent the water. That all these were furnished with a trunk, and lived in herds and browsed upon foliage and grass, there can be no doubt, for, with the above exceptions, their general structure is in all essentials that of modern elephants, the grinding teeth even being replaced, when worn, by new ones pushed forward from behind, as occurs with the two living species of elephant.

CHAPTER XII.

THE PLEIOCENE AND PLEISTOCENE LIFE-PERIODS.

Approach of the Glacial epoch—Its effect on life—Abundance and wide distribution of large herbivora—Migrations of Pleistocene animals—The mammoth both pre-Glacial and post-Glacial—Specimens from Siberian rivers—Size of tusks—Carnivora—Deer—*Cervus megaceros*—American edentata, the *Megatherium*, *Mylodon*, *Megalonyx*, and *Glyptodon*—Australian marsupials, *Diprotodon*, *Thylacoleo*, etc.—The extinct wingless birds of New Zealand, Queensland, and Madagascar—General conclusions from fossil remains.

We now enter that period towards the close of which so large an area in the Northern hemisphere became enveloped in a mantle of ice; when valleys were scooped out, and upon the surfaces of the rocks were left indelible marks of the passage of glaciers; when boulders, clays, and gravels were distributed by moving ice over lands where Meiocene palms had flourished and tropical animals had roamed; when the last traces of European corals, nautili, and similar denizens of warm seas disappeared before the cold advancing from northern regions. It is impossible to define with accuracy the limits either of time or space within which the alternations of lower and higher temperature exercised their

influence; but that there was a general advance of Arctic animals and plants southwards with a corresponding retreat of tropical forms, followed subsequently by the retreat of the Arctic fauna and flora to the latitudes they at present occupy, admits of no doubt. Whether or not, as some facts adduced by Dr. Croll seem to indicate, the earth had been subject to periods of Glacial action during the earlier ages of its history, and even so far back as Silurian times, the evidences of such action in geologically recent ages are conclusive. The physical effects of glaciation have been sketched in Chapter VI. The Northern hemisphere appears to have undergone a gradual refrigeration, probably beginning in Late Pleiocene, and continuing, with intervals of moderation, throughout Pleistocene times. In Europe, glaciation extended almost to the shores of the Mediterranean, and has been traced in America to the basins of the great Californian rivers, followed by the extinction of numerous plants and marine and terrestrial animals, of which the types now survive only in the warmer regions of the earth. The so-called "coralline" crags of Britain contain fossils which render it probable that no glaciation had subvened, at least in *Early* Pleiocene times, although the upper members of the series on the east coast of Britain present mollusca with characteristic Arctic features. These latter deposits, however, may be of Pleistocene age, but the subject is of too technical and intricate a character to be discussed with any advantage in a general work; it is of more importance to observe the rapid increase of forms of life

either generically or specifically allied to those still surviving. Thus, the mollusca alone examined in various deposits of this age prove to be of modern species to the extent of from forty to ninety per cent., according to locality; and the elephants, rhinoceroses, and other large herbivora, carnivora, apes, etc., of which a number are new, survive generically, though as species they are now extinct. In all classes of the animal kingdom a very decided tendency to assume modern characters is apparent, while some antiquated groups maintain their place for a time among their newer associates. Here we have the ancient hipparion, one of the earliest equine forms, ranging over the same plains in America with the true one-toed horse, *Equus excelsus*. Various species of extinct elephants had the widest distribution over Europe (including Britain), Asia, and America. Some difference of opinion has arisen as to their classification, owing probably to species being founded on individual differences; but the following represent indubitable species:—*Mastodon, E. antiquus, E. meridionalis, E. Americanus, E. Armeniacus, E. plainfrons, E. primigenius* (the mammoth), *E. Melitensis*, and *E. Falconeri*. The mastodon is no doubt entitled, from the peculiarity of its teeth, to be separated from all the others, and perhaps placed in a distinct genus. Specific names have also been given to the several forms of Indian mastodon; and there are, besides, the *Mastodon arvernensis* of Europe, and *M. Ohioticus* of America. Pleiocene Europe was certainly inhabited by numbers of *Elephas antiquus*, and *E. meridionalis* and

the mastodon of the valley of the Arno, which seems to be the same species as that from the Norwich crag, which contains besides *E. meridionalis*. At this time there can be little doubt that Britain was an integral part of the continent of Europe, for, in addition to the great proboscideans, a hippopotamus (*H. major*) was common to Britain, France, and Italy. Britain, moreover, produced the rhinoceros and tapir, and Europe such tropical forms as hyænas and monkeys, with the sabre-toothed lion, whose range extended to India and South America.

Several of the great herbivora possess considerable powers of accommodating themselves to a climate far more severe than that of their native country, in spite of the fact that they are destitute of any hairy covering, at least in mature life, although young elephants have a scanty growth of coarse bristles. Thus, notwithstanding the occasional severity of a European winter, the rhinoceros, hippopotamus, and both the African and Indian elephants live many years in confinement in latitudes whose mean annual temperature is at least twenty degrees lower than that to which they have been accustomed. There is no satisfactory direct evidence that the European mastodon, elephant, and rhinoceros were uniformly clothed with a hairy protection against cold; but this is not improbable, since we know that the mammoth (*E. primigenius*) was amply provided with hair and wool; and it might not unreasonably be inferred that the European hippopotamus, which associated with the reindeer in Pleistocene times, was not without

an efficient protection against a climate whose winters were then anything but mild. All these animals might, however, have migrated southwards at the approach of the northern winter, in which case hair would have been of no importance to them. To this one exception may confidently be made in the case of the *tichorhine* rhinoceros (so called on account of the bony wall separating the nostrils) found in Pleistocene deposits in Siberia, and still retaining most of its flesh and skin, which was well covered with hair. This species appears to have had a wide range from Siberia to the Pyrenees; but all we know certainly is that in its more northern habitat it was in some degree protected from the cold climate, which it probably would have had to encounter.

The post-Pleiocene, Pleistocene, or Quaternary period, as it is variously termed, is, both chronologically and zoologically, nearer to our own times than any other, and the period during which glaciation of the Northern hemisphere was most marked. Its deposits are very widely distributed, and include, besides formations contemporaneous with man, many in which no evidence of his presence has hitherto been detected. The lower forms of life are almost all specifically identical with those now existing, and all the higher have direct, but modified representatives in modern classes. Some very remarkable animals come into existence, some survive, others are extinct. The deposits are usually the result of disintegration of local formations, and their origin obvious—as the Glacial clays, gravels, etc.; fluviatile alluvium, sands, and gravels; cave earths and

crystalline limestones; volcanic products, breccias, marls, peat-mosses, and accumulations of drift vegetation. So far as our knowledge extends, only the northern area of the globe suffered glaciation, for nothing of the kind has been observed in the two southern continents of Australia and South America; in which Pleistocene formations occur abundantly, unaccompanied by any of the phenomena characteristic of Glacial action north of the equator. In the Southern hemisphere, we have, truly, contemporary glaciation of New Zealand, the lands within the Antarctic circle, Kerguelen Land, the Macdonald group, etc.; but this is normal glaciation, dependent on geographical position, or, as in the Alps and Himalayas, on elevation, and very distinct from the results of those secular variations in temperature which involved a vast extent of northern temperate lands.

While the task of determining, with any approach to precision, the geographical or secular limits of Glacial action in relation to animal and vegetable life is extremely difficult, and every method is open to criticism, it is possible to draw trustworthy general inferences from many indubitable facts. With all its defects, the only method of presenting an intelligible view of the subject is to generalize from the known data, neglecting for the moment such isolated facts as appear to tell against the generalization, but may be insufficient to outweigh it. The zoological testimony to glaciation in Pleiocene times has irresistible force. Mollusca of Arctic habit, such as *Pecten*, *Astarte*, *Scalaria*, etc., invaded

our latitudes, and the musk-ox, lemming, and reindeer ranged far into Central Europe—the latter as far south as the Pyrenees. These Arctic forms in all probability extended their range southwards after the elephants, rhinoceroses, and hippopotamuses had retreated before the cold which, on the other hand, favoured the northern animals; and, with the recurrence of a higher temperature, returned within the geographical areas they still occupy. Some of the proboscideans may have stood their ground in Europe, and survived throughout at least one of the less severe Glacial periods, for Professor Boyd Dawkins has proved the frequent association in Britain of the mammoth with the reindeer—the remains being found in deposits of unquestionable post-Glacial age; and he considers that the animal lived in Cheshire, the south of England, the region now covered by the North Sea, and possibly in Scotland, before the deposition of the boulder clays by glaciers and icebergs, basing his opinion on the succession of the deposits in the localities named, where mammoth bones, tusks, and teeth are found in considerable numbers.

Of all species of extinct elephants the mammoth was by far the most numerous, as would appear from the enormous quantities of their tusks brought annually from the Siberian rivers and the shores of islands in the Arctic Ocean. Northern Asia, then, was its stronghold, and here must have flourished an exuberant vegetation for the support of these herds of elephants, which inhabited the fertile valleys of the Lena, the Indighirka, the Obi, Yenisei, etc. What, then, were the hostile

agencies which led to their extinction? Among others, the gradual refrigeration of the climate suggests itself. In summer the herbage would be greatly diminished, and in winter would be almost entirely restricted to evergreens of the pine family—plants which we should scarcely think of as food for an elephant had not young shoots and cones of the pine been found in the stomach of the specimen examined by Lieutenant Benkendorf, which had recently been washed out of a bog when the ice melted in the river Indighirka in 1846. Assuming that the approach of the cold from the north had completely altered the character of Siberian vegetation, and further supposing that southward migration was prevented by a narrow sea, which might very possibly have followed the line of the Mediterranean, Caspian, and Black Seas, and extended across the present Asiatic continent, the extinction of the mammoth in the Siberian area would probably have taken place after no great interval. The Indighirka specimen, evidently one of the last of its race, as its huge frame still carried the flesh and hairy skin, had perhaps been reduced by the new conditions to subsisting on the scanty fare afforded by the young shoots put forth by the fir in that Siberian spring-time, when the animal trusted its weight to the treacherous morass, and became entombed for unnumbered centuries in the frozen soil.

The mammoth found on the banks of the Lena in 1800, and now in the museum at St. Petersburg, from which the accompanying figure is taken, presented the same characters. Much of the flesh had been eaten by

wild animals after the carcase had thawed out from the soil, but the head was still covered with skin,

FIG. 36.—*Elephas primigenius* (the Mammoth) from the river Lena.

which also enveloped the bones of the feet; the spine,

shoulder-blade, and extremities were united, and the great ligament of the neck remained, together with one eyeball and the integuments of the face. The ear bore a tuft of bristles at its tip, and the neck a long mane, and parts of the skin showed a covering of long dark bristles, with close reddish wool beneath. With these examples before us, it is hardly possible to doubt that the mammoth was contemporary with man in Northern Asia, as it undoubtedly was in France; and unless we credit frost-bound earth with the power of preserving so delicate a structure as the eyeball for untold centuries, some few mammoths would seem to have survived to the historical period.

An adult mastodon or mammoth considerably exceeded any existing elephant in bulk, but the most marked difference is to be seen in the size and shape of the tusks. These weapons are two upper incisor teeth, springing from permanent pulps and growing throughout life. In living elephants they are only moderately curved, and point in a direction well calculated for attack or defence; in the mammoth, and in less degree in the mastodon, they were curved upwards and outwards, with a slight spiral twist, which would render them inefficient implements for fighting, and the animal that carried a pair of these tusks, eight feet eleven inches long, like those of the Ilford specimen in the British Museum, must have been endowed with immense strength. Still larger must have been the owner of the tusk dredged from the bed of the Channel off Dungeness, which measured eleven feet in length,

and two feet four inches in circumference at the base. The heaviest tusk of an Indian elephant ever known—an old male, killed by Sir Victor Brooke—measured only eight feet, and weighed ninety pounds, which far exceeds the average in the still larger African species; but a single fossil tusk from Siberia has been found to weigh 160 pounds. The tusks of *E. antiquus*, on the other hand, were straighter and smaller.

It is hardly possible at this day to realize the fact that these colossal elephants were familiar objects in the Thames valley, in company with the rhinoceros, hippopotamus, and sabre-toothed lion. How numerous they were is attested by the brick-earth at Ilford, which has disclosed remains of a hundred mammoths, eighty rhinoceroses, and several specimens of the hippopotamus, probably brought together by floods in a "bight" of the river, when the Thames extended far into the county of Essex. Contemporary with these monsters were *E. Melitensis*, discovered by Dr. Leith Adams in the caves of Malta, and commonly known as the "donkey-elephant," scarcely five feet high; and *E. Falconeri*, the "pigmy" elephant, which did not exceed three feet.

The Spaniards are well known to have introduced into the New World the modern horse, whose wild descendants swarm on the vast Central and South American plains; but in Pleistocene times, that continent was tenanted by a species of fossil horse, which became extinct from some unknown cause. Among extinct European carnivora are machairodus; the cave lion (*Felis spelæa*), probably closely allied to the living species; and the

cave bear (*Ursus spelæus*), a more formidable animal than any existing bear; while the cave glutton hyæna and great grizzly bear no longer occupy areas in which they were common.

Bos primigenius (a huge species of ox), *Bos longifrons*, and *Bison priscus* (the aurochs), formed large herds in Europe, and the latter still survives in Lithuania, a remnant of the mammoth's contemporaries. The *Cervidæ* are represented by the reindeer, red deer, roebuck, moose, and the noble extinct Irish stag, *Cervus megaceros* (great horned stag), an animal of unrivalled size and beauty among its congeners, whose bones and antlers occur abundantly below peat-bogs and in lacustrine deposits principally in Ireland, but not uncommonly in English caverns and river soils. This magnificent "antlered monarch of the waste" stood twelve feet high from the ground to the top of the grand, broadly palmated antlers, which had a spread of at least ten feet, and at the most moderate estimate weighed between eighty and ninety pounds. What formidable weapons these would prove against even the large carnivora of the time! We can imagine the Irish stag dashing through the forest with his head lowered, carrying away branches as thick as a man's arm in his impetuous career; or standing at bay in a lake, surrounded by wolves, and cutting down all that ventured within reach. What a spectacle must have been the mortal combat between those two whose antlers were found locked together in the Limerick bog! Whole herds seem to have been swept away by floods or drowned by breaking through the ice, for the skeletons

of some sixty individuals lay together within an area of less than an acre in the Killegar bog. So numerous were the antlers in Ireland before they had become

FIG. 37.—*Cervus megaceros* (the great Irish stag).

objects of interest to palæontologists, that they were used to fence in gardens, and the victory of Waterloo was celebrated in a village in County Antrim by a huge

bonfire of the bones and horns of the Irish stag. No existing cervine species approached it in grandeur of aspect and carriage. The large skull of the American elk, and the short neck allowing the antlers to be easily thrown back on the withers, contrast unfavourably with the small, handsome head, and long but powerful neck of the great horned deer, whose limbs again suggest a combination of strength and activity unequalled in any living species of the family. It long bore the inappropriate name of Irish "elk," whereas, in fact, it does not belong to that section of the deer, but is rather to be considered intermediate between the fallow and reindeer.

Passing to the New World, some very singular groups of herbivorous animals present themselves in Pleistocene formations, and it is to be remarked that they reflect the characters peculiar to their living, but far smaller representatives on the same continent. Here is the head-quarters of the *Edentata*—possessing no teeth in the front of the jaws—the sloths, armadillos, ant-eaters, etc. Towards the close of last century, the bones of a colossal animal were exhumed from a considerable depth on the banks of the river Luxan, in the province of Buenos Ayres, to which Cuvier gave the name *Megatherium* (great beast). Casts of these were taken and put together in the British Museum, forming a complete representation of this enormous ground sloth, beside whose massive frame the largest hippopotamus would seem slightly built. From a critical study of its anatomy, Professor Owen has come to the following conclusions

with respect to its habits in life. So vast a weight could not have been supported in the manner of existing sloths, climbing, back downwards, among the branches of trees, but the animal must have passed its life upon the earth. Standing upon those pillar-like hind legs, of which every bone indicates extraordinary muscular power, and further supported by the short, thick tail, it would tear down trees of considerable size, in order to possess itself of their foliage, and the long, curved

FIG. 38.—*Megatherium Cuvieri.*

claws with which all the toes are provided, would assist it in maintaining a firm grasp of the wood. The *Scelidotherium, Mylodon,* and *Megalonyx,* forms allied to the above, but easily distinguished from them by dental and other characters, lived in a similar manner, and the two latter ranged as far north as the state of Virginia. These ancient representatives, then, of existing arboreal sloths were, on account of their huge size, necessarily

terrestrial animals. The living armadillos have their prototypes, too, in the *Glyptodons*—remarkable also for their large size in comparison with the armadillos, the proportions being as three to one—but the armour of the glyptodon, instead of consisting of movable bands, was a solid shield as inflexible as the carapace of a tortoise, and the skeleton was rendered still further rigid by ankylosis of the joints of the backbone.

We have seen that the earliest known mammals belonged to the marsupial order, and that they were distributed freely, during the SECONDARY and Early TERTIARY eras, over Europe, whence they have long since disappeared. They seem to have held their ground on the American continent from their first appearance there, and are still represented by the single genus *Didelphys*, including numerous species. In the far-distant Australasian region, however, the order flourishes, and is the dominant form of mammalian life. No fossil marsupials have been recognized in Australian rocks of the age corresponding to that which furnished Europe with them, although, with a fuller knowledge of the formations of Australia, it is probable that either the marsupial or lower monotrematous order will be discovered. That they should have appeared there suddenly in the Late Pleistocene age is contrary to our experience of the history of many other important groups. Here, again, the extinct TERTIARY types of the order are mostly colossal when compared with its living members. The largest kangaroo, if we concede it a height of six feet, would have appeared an insignificant creature

beside the fossil *Diprotodon*, whose skull was at least three times as large, and the rest of the body presumably on the same scale; so that this extinct kangaroo may easily have attained a height of eighteen feet. While the herbivorous division is represented by diprotodon, *Nototherium*, etc., they had a formidable carnivorous enemy in *Thylacoleo carnifex* (the executioner pouched lion), which transcended the proportions of any living predatory animal. Some doubt has been expressed by competent anatomists whether thylacoleo was carnivorous or not, although Professor Owen ranks it as such by the large sectorial teeth, which have no near analogy among the herbivorous orders in any class. At the present day Australasia produces two distinctly carnivorous genera of marsupials, *Thylacinus* and *Dasyurus*, besides others whose habits and dentition indicate similar propensities. It will be seen, then, that the extinct Pleistocene mammals of this province are still represented by living forms of the same order.

With the Island of Tasmania the southward extension of this group ceases, and the zoological evidence for the union of this island with Australia during the existence of such surviving animals as the kangaroo does not apply to New Zealand. Such of its TERTIARY strata as have been explored yield no marsupials; but the very large and important order of cursorial birds—those which possess no efficient wings, as the ostrich, emu, cassowary, rhea, apteryx, etc.—are represented by the extinct gigantic bird to which the natives gave the name Moa. In Professor Huxley's classification, this is in-

cluded among the *Ratitæ* (raft-like), because, like all its living congeners, the breast-bone is devoid of the usual "keel" or ridge for the attachment of the strong muscles concerned in the act of flight, and expanded into a flattened form. These cursorial (running) birds, whose wings are mere rudiments, are also characterized by their robust legs, the absence or aborted condition of the hind toe, and the flat sternum. When the first fragmentary remains of the moa were sent to Europe in 1839, Professor Owen placed the bird in its correct zoological position, which has been subsequently confirmed by the discovery of several complete skeletons, and portions of numbers of different individuals. This genus of fossil running birds (*Deinornis*) includes some well-marked species, of which the principal are *D. maximus*, *D. giganteus*, *D. elephantopus*, *D. didyformis*. All except the latter were very much larger than the largest ostrich or emu. From the complete skeleton of *D. elephantopus*, set up in the British Museum, we can form an idea of the appearance of these monster birds when in the flesh, and the leg-bones of specimens in the adjacent wall-cases are still more impressive. They might have belonged to the frame of the giraffe in another part of the museum, so massive are they. It is not at all unlikely that adult individuals of the largest species stood fifteen feet from the ground to the crown of the head, with corresponding robustness of body.

There is every reason to believe that these great birds were hunted for their flesh by some savage race, and thus extinguished; for their bones and egg-shells, charred by

fire, have been found in ancient cooking-places, together with burnt wood and stone implements; but there is no sufficient ground for supposing either that a single

FIG. 39.—*Deinornis elephantopus*, a species of Moa.

individual is now living, or that they have not been extinct for several centuries. That they survived to a comparatively recent period, however, is rendered almost

certain by the following interesting piece of evidence, which at least proves them to have been contemporary with a race of New Zealanders, whose burial customs were similar to those practised by the Maoris. In 1875 a human skeleton was discovered about sixty miles to the north of Auckland, New Zealand, buried in the sitting posture usual among the Maoris, and with it were the complete remains of a moa, included in the grave, no doubt, at the same time as the corpse. Still further colour is given to the supposition that the deinornis was coeval with man, by the discovery of a grave containing a human skeleton embracing one of the huge eggs of this bird in its arms, and by several instances of feathers and the skin of the legs being found adhering to the remains. In one point some species of moa differed from living cursorial birds in the possession of a fairly well developed hallux or hind toe, on which account Professor Owen proposed to include them in a new genus, *Palapterix*. The moas appear not to have been wholly confined to New Zealand, for the Leichardt Downs of Queensland have yielded satisfactory evidence of their presence there; and the Madagascan genus *Æpyornis* is considered to belong to the same large group of extinct struthious birds, of which the New Zealand *Apteryx* is in some respects the nearest living ally. Specimens of the eggs of the moa and æpyornis have been obtained, and their volume is equal to that of nearly three ostrich eggs. With some of the remains were little heaps of small stones, in the place originally occupied by the stomach, indicating a habit of the moa,

identical with that of living cursorial birds, of swallowing quantities of stones to aid in the digestion of their food.

With the exception of these extinct genera, all the Pleistocene bird remains belong to living species. The latter portion, then, of this period, not only as regards the avian class but all others, coincides zoologically with the period in which man has become the dominant animal.

Throughout this vast accumulation of strata, we have been enabled to trace on several important lines a striking connection between structures—such as the winged fore limb of the pterodactyl and the true wing of the bird, the avian resemblances of the hind limbs of some deinosaurs and the characters of the foot of Eocene equine forms—and we have regarded these as *lines of descent.* This may be a wholly untenable view, as those who feel unable to entertain any idea but that of independent acts of creation for every class, order, genus, species, and even variety of animals and plants which have inhabited the earth, will contend. On this latter hypothesis, however, an overwhelming body of facts must be accounted for by a gratuitous assumption, and a number of unconnected Creative acts is substituted for the continuous operation of natural laws.

When the palæontologist speaks of a "succession" of forms of life, beginning with a foraminifer, passing through every grade of organization, and culminating in man, he relies upon the positive evidence he is able to adduce. He might be asked, "Might not a reptile or a bird have existed in Laurentian, a mammal in De-

vonian, or an exogenous plant in Silurian times?" The reply is, "They are not found, while the lower orders occur in considerable abundance." But it may be further objected, "You can produce up to the end of the PALÆOZOIC era many inferior animals and plants, including fishes, and even the obscure reptilian proterosaurus, but since then an immense amount of denudation and reconstruction of strata has taken place which may have removed all trace of those higher organisms which you find in the MESOZOIC formations." It would be strange indeed that the lower forms should have been preserved in such numbers all through these stupendous changes of level, and in spite of so many destroying agencies, and that not one instance of the salvation of the higher organism should be known, had it existed. Again, the Jurassic period is extraordinarily rich in vertebrate air-breathing animals, which have been preserved most perfectly, although, since an archæopteryx left the impression of its feathers, and a pterodactyl the imprint of its wing membrane in the Solenhofen limestones, the earth has experienced changes fully as destructive as any we can conceive of as having affected it throughout the earlier periods. Were not the Oolitic rocks as competent to embalm the frame of a mammoth, a monkey, or a man, as the bones of the ornithosaurs and little marsupials, and the delicate wings of insects? Immense as is the physical break between the last MESOZOIC and first KAINOZOIC periods, it has not obliterated the records of the preceding rocks, among which, nevertheless, we seek in vain for any member of the numerous herbivorous

mammals which occupied the succeeding Eocene land. That ancient river basin, which holds the London clay in an amphitheatre of chalk and sands, contains species of nautilus, whose iridescent colours have not wholly departed, but not one tusk, tooth, or bone of the elephants, hippopotamuses, and rhinoceroses, whose common domain in subsequent periods was the valley of the Thames.

If, as modern science holds, the earth has written the record of her history in the rocks, it devolves upon us to collate all the evidence, and draw the most consistent conclusions from it that may be possible. No competent naturalist will now dispute the force of the evidence for a long succession of organized beings, in which the lower have preceded the higher forms; but the evolutionist contends further that the latter have been elaborated from the former by the impetus of development inherent in all organic matter—subject, however, to very complex conditions and influences both internal and external; and the ablest of his opponents will be the readiest to admit the strength of his position. This may not prove to be *ultimate* truth; but the hypothesis has afforded a better explanation of the phenomena of life than any hitherto propounded, and has stimulated observation and comparison of facts to an extent unparalleled in the annals of biological research.

TABULAR VIEW OF THE KAINOZOIC SYSTEM OF ROCKS, WITH THEIR PREVAILING OR CHARACTERISTIC FORMS OF LIFE.

KAINOZOIC, or TERTIARY.	PLEISTOCENE.	More or less well represented in all geographical areas. Glacial accumulations. Raised beaches, cave earths, brick earths; lacustrine muds and sands; fluviatile deposits of sand, gravel, etc., in beds and deltas; calcareous and silicious deposits from springs, etc.; breccias; lava and other volcanic products; peat-mosses. Great majority of organic beings of all classes belong to existing genera, and often to living species. *Rhinoceros Etruscus*, *R. megarhinus* and *R. tichorhinus* (the latter woolly, abundant in Europe). *Hippopotamus major*. *Mastodon Ohioticus*. *Elephas antiquus*, *E. meridionalis*, *E. primigenius*, *E. Americanus*, *E. Melitensis*, *E. Falconeri*. *Machairodus*; *Felis spelæa*; *Hyæna spelæa*; *Ursus spelæus*. *Bos primigenius* and *B. longifrons*, *Equus fossilis* (possibly identical with existing horse). *Cervus megaceros* (great Irish stag). *Megatherium*, *Mylodon*, *Megalonyx*, *Scelidotherium* (gigantic American edentates). *Glyptodon* (South America; allied to armadillo). *Diprotodon*, *Nototherium*, and *Thylacoleo* (Australian herbivorous and carnivorous marsupials). *Deinornis* (cursorial birds; New Zealand). *Æpyornis* (Madagascar). *Didus* and *Pezophaps* (razorial birds (?); Mascarene Islands). Fossil remains of MAN in caves and breccias. Implements of stone, bone, and horn. Lake-dwellings, shell-mounds, kitchen-middens, and other evidences of great antiquity.
	PLEIOCENE.	Well developed in Britain and Europe generally, North America, and India. White and red "Crags" of Britain, sub-Apennine beds, newer Siwâlik of India, sands, conglomerates, marls, etc. Vegetation assumes partially the character proper to temperate regions. Mollusca from 40 to 90 per cent. of existing species. *Mastodon Arvernensis* (British and Continental). *Elephas meridionalis* and *E. antiquus*. *Rhinoceros Etruscus* and *R. megarhinus*. *Hippopotamus major* and *Tapirus Arvernensis*, both European. Bears, Hyænas, and *Machairodus*, distributed over Europe, Northern India, and South America. Apes (British and Continental).
	MEIOCENE.	Poorly developed in Britain, well in Continental Europe, India, North America, and the Arctic regions. Marine and lacustrine limestones, shelly sands, clays, lignites, and Arctic coal. Siwâlik beds of India, Hempstead and Bovey Tracey beds, deposits of Switzerland, France, Germany, Greece, and America. Flora abundant, of sub-tropical character in temperate regions of the Northern hemisphere. Exuberant vegetation, extending far within the Arctic circle. Red coral first appears. Lower forms of marine life abundant. Large sharks and true cetaceans. Frogs and salamanders. Gigantic land tortoises. Marine crustaceans. Insects representing the principal existing orders. Swine, tapir, deer, sloth, camel, giraffe, rhinoceros, and hippopotamus, *Brontotherium*, *Titanotherium*, *Sivatherium*, *Deinotherium*, *Mastodon*, *Machairodus* (the sabre-toothed lion), porcupines, rabbits, mice, beavers, squirrels, weasels, marmots, hedgehogs, bats, apes, and marsupials.
	EOCENE.	Well represented in Europe and North America. Sandstones, limestones, sands, clays, marls, coral rags, and lignites. Bembridge, Headon, Osborne, Bracklesham, and Bagshot beds; London clay, Blackheath, Reading, Woolwich, and Thanet beds. Flora allied to existing forms; exotic in North Temperate zone. Nummulites abundant. Fishes allied to existing orders. Reptiles—crocodiles, alligators, gavials, and turtles. First appearance of serpents. *Deinocerata*. *Palæotheria*. Equine forms, *Orohippus*, *Hipparion*, *Anchitherium*. *Zeuglodon* (a cetacean), *Halitherium* (a siren), *Chæropotamus* and *Hyopotamus* (allied to swine), *Anoplotherium* (allied to swine and ruminants). New bird forms—*Dasornis*, *Gastornis*, *Argillornis*, *Lithornis*, *Odontopteryx*. Bats. Marsupials. Ammonites, Belemnites, Hippurites, Enaliosaurs, Deinosaurs, and Pterodactyles are all extinct.

CHAPTER XIII.

FOSSIL MAN.

Fossil man a recent discovery—The monogenistic and polygenistic theories—Man considered from the zöological point of view—His structure and relationships with lower animals—Speech—Growth of pictorial and symbolical records—Primitive habits, weapons, and tools—The Palæolithic and Neolithic periods—French troglodytes—Their manner of life—Contemporary with extinct animals—Physical characters—Art—British caverns and their occupants—Chronology—The Neanderthal skull—Kitchen-middens—Lake-dwellings—The Guadaloupe fossils—Conclusion.

At the meeting of the British Association for the Advancement of Science, in 1878, Professor Huxley, addressing the Anthropological Section, observed—"Lastly, great progress has been made in the last twenty years in the direction of the discovery of the indications of man in a fossil state. My memory goes back to the time when anybody who broached the notion of the existence of fossil man would have been laughed at. It was held to be a canon of palæontology that man could not exist in a fossil state. I do not know why, but it was so; and that fixed idea acted so strongly on men's minds that they shut their eyes to the plainest possible evidence. Within the last twenty years we have an

astonishing accumulation of evidence of the existence of man in ages antecedent to those of which we have any historical record. What the actual date of those times was, and what their relation is to our known historical epochs, I do not think anybody is in a position to say. But it is beyond all question that man, and not only man, but, what is more to the purpose, intelligent man, existed at times when the whole physical conformation of the country was totally different from that which characterizes it now."

It will be unnecessary here to enter into all the arguments by which it has been sought, on the one hand, to maintain that all existing varieties of man have arisen by differentiation from one common stock, and on the other, that the great human families have descended from several distinct stocks whose characteristics have long remained in the main intact; for this question is independent of that of man's high antiquity as an inhabitant of the earth,—but it may be remarked that the preponderance of opinion is now in favour of descent from one type, rather than from several. The geologist cannot exempt man from the operation of those laws of variation which, he is well assured, have determined the greatest modifications in other classes of animals, even should he consider it probable that man is far less plastic than they in virtue of his intelligence, which, however low it may be, will still enable him to offer considerable resistance to climate and other external influences not possible to the lower animals.

Mr. A. R. Wallace has proposed an ingenious and

philosophical explanation of the known fact that, during periods within the range of historical observation, no considerable modification of the physical or mental characters of any race of man has taken place, although that race has been subjected to influences differing widely from those natural to and presumably favourable to it. On the presumption that mankind is descended from one stock, Mr. Wallace attaches great importance to his mental powers as a factor in preserving varieties which had once arisen. He thinks that the tendency to variation would be greater while the mental faculties were comparatively feeble, diminishing as the exercise of these led to the establishment of communities having primitive social customs tending to separate large bodies of men from their fellows, and to restrict marriage within narrower limits. Thus, differences already established would be preserved and intensified, and accumulated experience in the arts of life would render those external influences, which had originally determined modifications of type, less and less operative in effecting further changes; while, marriage being limited to an area within which all the elements of the variety predominated, the type would tend to become fixed. Whether or not man has descended from some yet undiscovered fossil form intermediate between the anthropoid apes and himself—and that must be entertained as something stronger than a mere possibility if the doctrine of evolution is to remain consistent with itself—modern philosophy regards his origin as subject to the same methods of investigation, and treats

whatever evidence may be forthcoming in precisely the same manner as when dealing with inferior forms of life. Having taken up for examination one end of the chain of being, we cannot logically shrink from following it to the other, should it ultimately lead to the connection of man, by direct descent, with so lowly an organism as an ascidian.

From the very first moment when we meet with indubitable evidences of the tenancy of the earth by the human race, it is differentiated from any existing or known extinct species; but this fact does not outweigh the numberless inferences from his structure that man has a genealogical relationship with these. The structural differences between him and the lowest apes are less than those between apes and any lower form; and when we compare the lowest varieties of the human species which may be considered to be entitled to rank as man, with the highest apes, the most critical anatomy is unable to draw a strict line between the absolute brute and the absolute man. The power of speech seems to present a character by which any man can at once be distinguished from any ape, and has been relied upon as offering an impassable barrier. This distinction would indeed be most important were it real. Reduced to its elements, speech is merely one mode of intercommunication between animals of the same genus—in this case man—by means of articulate sounds. But animals in every zoological class, whose organs permit any kind of vocal expression whatever, can be proved most conclusively to communicate to one another, not only their

emotions, but facts previously unknown to those individuals of their species whom they desire to inform. The vocabulary is limited, it differs in kind from ours, but no one who has attentively observed animals can doubt that it produces analogous results, or that the animal is not perfectly conscious of the effect it intends to make upon its fellow. Further even than this, animals long familiar with man learn, within certain limits, his language. How completely would an Englishman fail in driving a team of French horses at the plough! and, *mutatis mutandis*, how vain would be the efforts of a Frenchman to direct by his voice a Sussex team! Can it be said that these animals respectively have not learned English and French to a limited extent? Similar examples could be multiplied indefinitely from the domestic relations of man and brutes. We understand to no inconsiderable degree the facial expression and gestures of monkeys, and they ours; and our emotions and theirs are rendered by very similar vocal expressions. If we saw a number of savages sitting in the topmost branches of a cocoa-nut palm, and pelting us with the fruits in reply to our volleys of stones; or rolling down stones upon us from the sloping sides of a hill, jabbering the while in language of which we could not understand a single word, would it occur to us to suppose that they were not communicating with each other in articulate speech? All this has been observed in the case of monkeys, and it does not seem possible to escape the conclusion that their chattering has a meaning for one another, though none for us. Huber,

Lubbock, Waterhouse, Tegetmeier, and others, have proved that communities of insects convey intelligence of facts to their own kind by means of their antennæ, which must assuredly be a form of speech similar to our deaf and dumb alphabet, and not more surprising. The concerted actions of two or more animals are almost always accompanied by the voice in repeatedly varied tones, as if direct communication were going on between beings who wished to attain an object present to the mind of each. It is to be observed, too, that the sounds made by animals are chiefly monosyllabic; and so, philologists tell us, are the languages spoken by primitive races of man, compounded of quite simple elements, certainly within the compass of an ape's voice. Travellers whose veracity and ability cannot be impugned, have described long conferences held by monkeys, where one individual addressed the assembly at great length, fixing the attention of all upon himself, and quelling any disturbance by a loud and harsh cry, which was at once recognized and obeyed by the multitude. That this should be purposeless is incredible, and if it have a purpose, what name can we give the vehicle of the purpose but speech? Archbishop Whately evidently had a strong conviction that a meaning intelligible to themselves was couched in these utterances, when he said that man "is not the only animal that can make use of language to express what is passing in his mind, and can understand, more or less, what is so expressed by another." If this be so, man is not as sharply distinguished from animals in this respect as has been maintained.

Forming so well-defined a group as do the two great families of *Simiadæ* and *Cebidæ*, and so closely as man is admitted to be allied to them, there is nothing extravagant in the supposition that they may all have diverged from a common ancestral form, or that man had an immediate precursor, yet to be discovered in a fossil state, who possessed little more power of speech than an ape, who did not know the use of fire, and did not bury its dead, but walked habitually upon its hind limbs. This human precursor may have inhabited as comparatively limited an area as the African Bosjesman or gorilla, and his remains may be buried at this moment in some submerged stratum. All the human races which now tend to bridge the interval between the highest man and the highest ape are on the way to extinction under the irresistible pressure of civilized man, and when this shall have been completed, the gulf between the surviving species of man and the ape will appear very wide; but history will have it on record that the interval was once spanned by species and varieties of the genus *homo*, differing widely from one another, and all inferior to the surviving type. The Caribs and Tasmanians have passed from existence, while the Australians, New Zealanders, aboriginal Americans, Eskimo, and some others are fast succumbing; and all this has taken place within the historical period or quite recently, whence the disappearance of man's precursor and his own survival are not very surprising circumstances.

If it be contended that the type of man represented

by Newton, for instance, and the type represented by the "Hottentot Venus" are on the same zoological plane, and do not in the least degree indicate a series descending from Newton to the Hottentot, it must nevertheless be admitted that the human intellect is capable of a growth so vast as that which distinguishes the great philosopher from the Bosjesman woman; of whom Cuvier remarked that the pouting of her lips, her abrupt fantastical movements, her smile, etc., reminded him forcibly of an ape, and that the bones of the skeleton possessed many distinctive animal characters. The immense intellectual interval between these two human forms would not be disputed, and it would tax anatomy and psychology to show a greater physical and mental interval between this Bosjesman and an ape.

Modern anthropology, which includes human palæontology, maintains two leading propositions: first, the descent of man from a primitive creature who would hardly rank with the most degraded existing race; and secondly, the gradual and exceedingly slow development of all the intellectual and moral faculties which at present constitute his superiority. The first proposition, as has been seen, although supported by very weighty considerations, remains unproved; but around the second a vast mass of direct evidence of the most cogent character has been grouped.

For much of this we are indebted to the industry and scientific acumen of the French, whose country affords some of the most distinct traces of primitive man. These consist, in the first place, of flint imple-

ments, obviously manufactured by human skill, but unaccompanied with human bones; and in the second, of implements wrought from flint, stone, horn, shell, and bone, associated, *in situ*, with parts or entire skeletons of man and some extinct animals. French archæologists claim for a part of this series an antiquity reaching back to the Pleiocene and even Meiocene periods, the truth of which would, of course, depend upon the accurate determination of the geological age of the Pouancé shell-heaps and the Thenay deposits, whence the implements were derived. Indisposed as we may be to admit the existence of man in Meiocene times, there is no question of his presence in Europe during the life-period which included among its then living fauna the mammoth, rhinoceros, cave bear, hyæna, reindeer, etc., and probably sabre-toothed lion, some of which are extinct, while the others are geographically remote.

History and tradition go comparatively a very short distance back towards the races which peopled Europe before the extinction of the mammoth; therefore we are restricted to their weapons, tools, ornaments, and bones for all knowledge of their manner of life and position in the scale of civilization. It is almost needless to remark that man must have been anterior to any kind of record of himself in every region of the globe. Millions of human beings inhabiting Africa and Oceania, although they have made some progress in social organization, and have brought the earth under cultivation and domesticated animals, possess not even the most rudimentary method of recording events. Written

language implies a marked advance in culture, and has, perhaps, been one of the greatest factors in human progress, because it has enabled man to fix for the use of future generations elements of knowledge acquired during ages of experience, and in every direction promoted the conspicuous ascendancy he has attained over animate and inanimate nature. It can be shown how this arose from the first promptings of his æsthetic sense—the love of form and colour—from the rude, meaningless scratches upon favourite weapons, to the delineation of simple objects, of animals and plants; whence picture-writing, of which the ancient Mexican is a complete and Japanese a partial example; and lastly, the reduction of the cumbersome pictorial to the symbolical method.

The history of every modern civilized race negatives the belief that man was, *ab initio*, endowed with any of the knowledge which has led to his commanding position. On the contrary, the record is one of trial and failure through long ages, and of experiment crowned at last by attainment. A hundred points along the line of progress at once suggest themselves. We may contrast the civilized world before and after the discovery of the principle of the steam-engine! It has revolutionized civilization and extended man's dominion in a marvellous manner—a great step among many others relatively as great. In the uncultivated races we have a graduated scale of progress, touching at its lowest extremity the very dawn of intelligence, and at its highest rising to a parallel with the condition of those semi-barbarous

Teutons, who, in virtue of their immense numbers, swept aside the power of Rome, and at this moment represent the highest level of social and intellectual progress.

By the light afforded by these primitive races we are enabled to decipher much of the history of the struggle upwards from barbarism to civilization. When in our valley gravels, drifts, and caverns we find weapons fabricated from certain materials, the remains of food, and domestic utensils, and indications of habits common to numerous existing savage races, we infer that the primitive men of Europe had reached a condition commensurate with that of contemporary barbarians. In both cases the materials are the same—stone more or less easily worked, but hard enough for durability, animals' bones and horns, shells, and wood—the patterns of the implements are always very similar, and frequently identical in regions separated by half the circumference of the earth. Urged by necessity but restricted by its surroundings, the mind of man appears to have advanced slowly along a well-defined track, by steps so similar that they are radically indistinguishable from one another, whether they are compared in Denmark or New Zealand, in Central America or France. In all times and all regions, too, human progress can be traced through three stages—that of the hunter of wild animals, succeeded by that of the herdsman and agriculturist; although these modes of life frequently co-existed to a greater or less extent, as is actually the case in the interior of Africa. It is easy to see how

large communities grew up around the centres of agriculture, how nomadic gave place to fixed habits of life, necessitating in their turn permanent habitations, division of labour, and co-operation for defence. Upon such foundations have been raised all the arts of civilized life. Wherever civilization is submitted to a process of analysis, it eventually resolves itself into the stone axé and the flint arrow-head, betokening a contest with nature often more severe than that undergone by any wild animal in the struggle to maintain itself.

Man's first durable implement was obviously a stone. He found many of angular form lying about, with which it was possible to hack flesh and bone rudely, and these could be improved by chipping them with others. The facility with which flint and quartzite lend themselves to the operation of chipping to an edge, and their hardness, have rendered them favourite materials among prehistoric workmen, while their extreme durability has preserved them as records through long ages. Even perpetual rolling in drift gravel has not always sufficed to obliterate the character of the workmanship; but where they have lain imbedded in cave earths, or covered by stalagmite on the floors of caverns, protected from all eroding agencies, they appear as fresh as if manufactured to-day.

Whatever material has been used, the character of the work expended upon it supplies an important chronological test of its antiquity. Archæologists, then, divide the Stone Age into the Palæolithic (ancient stone) and Neolithic (new stone) periods; the former

characterized by the rough workmanship and unpolished surface of the implements, the latter by the high finish and elegant form which at once proclaim the hand of a more skilful artificer. To some extent, these periods may overlap each other, but the broad distinction thus established is supported by concurrent evidence that the old and new stone periods correspond with lower and higher degrees of advancement.

So far back as 1797, flint implements were discovered associated with the bones of fossil elephants, etc., in the gravel beds at Hoxne, in Suffolk; but the find was unconnected with sufficient data from other sources to warrant any definite conclusions. Subsequently, researches on the Continent disclosed similar remains in the limestone caverns of France (1828), in those of the Meuse (1833), and at Menehecourt (1841), which, however, received little attention at the time. Only within the past twenty years have these researches been estimated at their true value, and sustained by the investigations of numerous English and French geologists into the contents of caverns, fissures, rock-shelters, and river-deposits in various parts of Europe.

To MM. Lartet, Christy, and Verneuil, and Dr. Falconer we are indebted for an exhaustive examination of the series of caverns, etc., with their remains, in the calcareous rocks on the banks of the river Vézère (department Dordogne). Here, at intervals, along the banks of the river, are several stations inhabited by troglodytes (cave-dwellers) of the Palæolithic period. Naming them in the order believed

to represent their occupation by people gradually progressing in the arts of life, they are: 1. Le Moustier; 2. Cro-Magnon; 3. Upper Laugerie and Gorge d'Enfer; 4. Lower Laugerie, Les Eyzies, and La Madelaine. The eroding action of the river itself has provided us with a chronology, from which it may be deduced that a vast interval of time elapsed between the occupation by man of the Moustier cave, some hundred feet above the present level of the river, and his occupation of the Madelaine, but a short distance above the present flood mark. The Vézère troglodytes, then, must have witnessed, generation after generation, the gradual erosion of this valley to a depth of at least a hundred feet. At every station there are indubitable signs of man's tenancy (tools and weapons, and bones of animals used as food, and, at Cro-Magnon, the bones of four or five human beings), covered with river-mud swept into the cave during floods, with stalagmite, or with material fallen from the roof. The large, rude implements in the Moustier station—lance or spear points chiefly—unaccompanied with bone weapons, point to a low degree of civilization. The inhabitants probably knew nothing of the art of capturing smaller game, for not a single fish or bird bone is found in this cave. The Cro-Magnon people made lighter stone weapons of better finish, and occasionally horn dart-points, with which they managed to secure smaller game—the hare, fox, goat, and crane—besides the reindeer, mammoth, cave lion, and bear. The numbers of skin-scrapers, too, suggest that they were clothed in the hides of animals.

At Upper Laugerie, the implements are all of flint, lancet-shaped, admirably proportioned, and of three sizes, adapted for arrow, javelin, and lance points respectively, and designed to be fitted to wooden or bone shafts. The occupants of the Gorge d'Enfer show a decided advance upon their predecessors. For all lighter weapons, such as arrows and darts, stone had been abandoned in favour of deer's horn and bone—materials more easily worked, but quite as efficient as flint. Now the latter was fabricated into little tools for working the former; and we have a large assortment of useful implements, among them bone awls and needles for piercing and sewing the skins, which were doubtless made into clothing, with strips of hide or the tendons of the animals whose bodies furnished the most important of their industrial productions. A period of ornamentation and artistic effort characterized the later stations of the Lower Laugerie, Eyzies, and La Madelaine. Then the horn arrow-heads were furnished with a regular series of barbs on each side, which would steady the missile in its flight—a fact of which the workman must have known the significance; and harpoons, barbed on one side only. If we may judge from the quantity of salmon bones in these caves, the later troglodytes used their harpoons to good purpose in the river Vézère. These were large fish, and salmon only; whence it has been inferred that they had no nets, which would have taken fish of all sizes, but selected those most readily secured with the harpoon. We may notice, as an interesting circumstance, that the salmon cannot at the

present day ascend the Dordogne or its tributaries, owing to a bar of rock near Lalinde—indicating a considerable change in the physical features of the valley since the last of the cave-dwellers inhabited it. The Moustier people were evidently in the rudest condition; but those who fabricated cunning weapons and useful implements from horns and bones, and carved outlines of animals upon various substances, as did the men of La Madelaine, had begun to express their perceptions of form in no contemptible fashion; and thus far had attained to a comparative degree of refinement, since it afforded them *pleasure* to exercise their faculties thus.

These men were still in the Palæolithic period; for not one polished implement, nor any fragment of pottery, is found in their stations. They were surrounded by ferocious carnivora, which sometimes fell victims to their weapons; the mammoth still tenanted the valley, and the reindeer was so plentiful that it was one of the commonest sources of their food at all seasons of the year, and not at all improbably a domesticated animal. They were mainly, if not entirely, hunters; their feasts were supplied with the flesh of the huge mammoth, the bison, ox, horse, deer, wolf, fox, and goat, and their light arrows brought down such birds as herons and cranes, which the patient savage could approach with cat-like stealthiness among the reeds on the river-bank.

What were their physical characteristics? The distinguished anthropologist, M. Paul Broca, rates them very high. Taking the Cro-Magnon remains as the type

of the earlier troglodytes, he states that they were a tall, robust race, with large, well-curved crania, even surpassing the average French peasant of the present day, and the development of the anterior lobes of the brain shows them to have been possessed of an energetic cerebral organization. The tibia, on the other hand, is flattened, and the jaw considerably prognathous; but, notwithstanding these and some minor marks of inferiority, the remains present characters common to the noblest types of man—stature, strength, eranial capacity, and constitutional vigour.

Among the more interesting relics of their social life are the numerous deer-horn batons of command or insignia of rank; shells pierced for hanging on the neck as ornaments (some of them, curiously enough, fossils of Meiocene age); the teeth of animals drilled to form necklets or bracelets; and a whistle made by drilling a reindeer's phalange, with which one can to this day produce the shrill rallying call of the old troglodyte huntsman. But their skill as artists is most conspicuous, and raises the later cave-dwellers high in our estimation. The figures, executed upon horn, bone, stone, and in one case ivory, are generally in outline, and always in profile, like the first attempts of children. There is not a single attempt at perspective. The outline figures include the mammoth, reindeer, horse, ox, bison, fishes, a human hand and profile, and some flower, probably a rose. The carvings or reliefs consist only of a reindeer and a woman. It seems pretty certain that the drawings are of earlier date than the carvings, or at least

that the former art preceded the latter. They are naturally of various degrees of excellence, but some are replete with spirit and action. This is especially the case with the combat between several reindeer, which exhibits three or four of these animals in conflict. One seems to have been turned upon its back, in evidence of its defeat—a method of representation common in

FIG. 40.—Fight between Reindeer, scratched on slate; from the troglodyte stations on the Vézère.

Assyrian art—the troglodyte artist being unable to render the difficult perspective of the limbs and body relaxed in death. In addition to this crucial proof of the contemporaneous occupation of the valley of the Vézère by man and the reindeer, already substantiated by the constant association of their remains, we have the very remarkable drawing of the mammoth on a piece of ivory from the Madelaine cave. Did we not know some-

FIG. 41.—Prehistoric drawing of the Mammoth, on a slab of ivory; from the Madelaine station on the river Vézère.

thing of the mammoth in the flesh from the Siberian specimens—his up-curved tusks, concave forehead, and long mane—this *chef d'œuvre* of the troglodyte artist would never have commanded the admiration with which we must now regard this savage huntsman's rude but vigorous effort to translate, with the point of a sharp flint, his observation of the animal into a permanent record of the zoology of his time—an expression of noble endeavour not unworthy of the greatest living genius.

From the quantities of coal and cinders in these French caverns, it may be safely assumed that their occupants inhabited them permanently, and kept up their fires; for the climate which suited the reindeer would render a warm shelter in winter absolutely necessary to man. Consequently, though hunters, they were not nomads. Great as must have been the interval of time between the Moustier and Cro-Magnon race and the people of the Madelaine—represented by the erosion of the river-bed eighty-five feet—we must remember that the mammoth was still living, when a cave, now only some fifteen feet above the present highest flood level, was tenanted by man. Between that last period and our day, then, the lapse of time must have been enormous as compared with the historical era, for history nowhere carries us back to the age of the mammoth; yet the most modern of these troglodytes had not entered the Neolithic period—the period of polished weapons, of pottery, of agriculture, and of textile manufactures—itself to be followed by the period of metals, which brings us to the dawn of history.

A general survey of the British caverns in Devonshire, Yorkshire, and Derbyshire leads to the following main conclusions:—That man was contemporary in Britain with the mammoth, reindeer, rhinoceros, cave bear, lion, hyæna, etc.; that he was in the unpolished stone age; that he was a hunter; that he made no pottery; and that he had not attained to the skill in ornamentation, much less reached the artistic standard exhibited by the cave men of France. Many of the bone weapons are excellent in design and finish, notably the harpoon from Kent's Cavern; but the British troglodyte had either no leisure or no artistic promptings. Nevertheless, it would not be safe to conclude, from the ordinary specimens of his work which we do possess, that extraordinary efforts were not made by some individuals, even superior to the engraving of the head and fore quarters of a horse, on the portion of a rib of some animal, which was found recently in Robin Hood's Cave, Creswell Crags, Derbyshire. Britain has not hitherto furnished any Palæolithic sepulchre, like that of Cro-Magnon, with complete, or nearly complete skeletons and skulls of both sexes; and the best British human fossil—the portion of an upper jaw containing four teeth, from Kent's Cavern—would not justify any anatomical determination of its position in the zoological history of man. Thus far, at least, we may go. Hermetically sealed in stalagmite, deposited on the floor of the cavern by water dripping from the roof, this jaw lay *below* the remains of extinct mammals; while beneath all were bone and stone implements of human workman-

ship, equally firmly fixed in a natural limestone cement. Intermixture of these relics was precluded by the nature of the deposit continually forming over them and sealing them in a matrix of crystalline limestone, and there can be no doubt that their order of superposition corresponds with a chronological succession, which would give to the implements and bones of man an antiquity at least equal to that of the rhinoceros, cave bear, mammoth, etc., if not greater. Many successive generations of men probably lived here and fed upon the animals whose charred and broken bones lie scattered over the different layers of the floor, associated with charcoal, flint flakes, weapons, etc., and long periods may have elapsed during which the cave was the resort only of bears, hyænas, and lions. Perhaps that human jawbone was carried there by one of these large carnivora. Teeth-marks characteristic of the hyæna, on the bones of herbivorous animals, testify abundantly to his having made this a lair.

Although the west of England has afforded the clearest evidence of man's co-existence with the extinct fauna of the British Islands, the same conclusion may be drawn from the cave deposits of other localities.

In endeavouring to arrive at some estimate of the interval between the era of the Devonshire cave men and the present day, Mr. William Pengelly compares the physical features of the district in the troglodyte period with those it presents now. These lead him to the conclusion that the valleys of Ilsham and Brixham have been scooped out sixty feet and a hundred feet

respectively since the last fluviatile deposit was left in the caves. Still more suggestive, perhaps, of the long lapse of time are the human remains in the submerged forest-beds at Pentuan, and at Carnon in Falmouth harbour. Everything here points to very slow subsidence of the forests, the stumps of the trees being frequently in a vertical position, and gradual accumulation above them of a mass of detrital matter regularly stratified. In the process of mining for tin these deposits were passed through, and human skulls were found in one case about forty feet below the surface, and in another still lower in the forest-bed itself. This very considerable change of level in the west of England had been already completed when Diodorus Siculus described the district—a few years after the Christian era—in terms which would apply exactly to it now. But before then occurred the deposition of from twenty to forty feet of *detritus*, before that the subsidence of the forest, before that its growth, and during its growth the presence of man in Devonshire as a contemporary with extinct animals, of whose existence the oldest legends and traditions have not preserved the faintest trace, although they must have been objects of special attention to primitive man, and were likely to have survived in tradition had it not been obliterated by the slow lapse of time.

Among other human remains from Engis, Mentone, Bruniquel, Canstadt, etc., the celebrated Neanderthal skull has been an object of special attention to anthropologists. It belongs certainly to the mammoth age, if not earlier, and if it represents a race and not merely

an individual, that race would lie in a position intermediate between the lowest man and the highest ape. Its isolation, however, forbids any general conclusion to that effect. In *capacity*, the cranium is human, while the superciliary arches and the brow are distinctly apelike. Professor Huxley sums up with the remark that "the Neanderthal skull is, of human remains, that which presents the most marked and definite characters of a lower type."

Testimony corroborative of man's presence in Europe at a very remote period, though probably subsequent to the age of great herbivora and carnivora, comes from the refuse-heaps termed "kitchen-middens," particularly abundant in the Scandinavian peninsula, but not unknown elsewhere, *e.g.* in Brazil, Scotland, and New Zealand. These frequently very large heaps seem to have been formed by the inhabitants of considerable villages, probably living in huts, who cast all the *débris* of their feasts into one spot—broken and charred bones, ashes, fragments of earthenware, shells, etc., with which some implements became mixed. Here are direct evidences, in the form of more or less polished implements and rude pottery, that the midden-makers had advanced somewhat. Moreover, since their habitations would be in close proximity to the village refuse-heap, they would seem to have dwelt in some kind of artificial structure. Here, at all events, we have the dawn of the Neolithic period, with, probably, a more genial climate and a decrease in the number of predatory animals, owing, perhaps, to the increase of the human race.

More distinctly still is the new or polished stone period, marked by the series of "lake-dwellings," which indicate a very considerable population in Europe at a time when the use of metals was imperfectly known, and stone was still employed for the more massive implements. Man had now adopted a permanent artificial habitation, constructed on one general plan, in Switzerland, Germany, Austria, Denmark, France, Ireland, Scotland, and Wales. Of these buildings, differing in details, some are undoubtedly much older than others; but the limits of this work permit of only a brief description of the typical forms. They were all built at a greater or less distance from the shore of the lake, sometimes connected with the land by a wooden causeway, sometimes without, implying the use of wooden or skin canoes in passing to and fro. Usually, wooden piles, roughly hewn or charred to a point and driven into the bed of the lake, supported a platform of transverse beams, with numerous cross-pieces, overlaid by mud or clay beaten down. Upon this substructure were raised huts, in most cases rectangular, but sometimes circular, made of upright stakes bound together by thin branches plastered with clay, and surmounted by a reed-thatched roof. In some instances, shoals and islands in the lake were taken advantage of, and in others mounds were artificially made by transporting quantities of earth, stones, etc., to the site upon which it was intended to erect the dwelling, as is frequently the case in the Scotch, Irish, and Welsh "crannoges." Whatever may have been the object of all this labour—whether as

a defence against predatory animals or human foes—it was accompanied by great ingenuity and a command over materials altogether unapproached by the primitive cave-dwellers or the midden-makers.

These people had long since abandoned a nomadic life, and were enjoying the advantages of social intercourse, in itself a powerful factor in civilization. The neighbourhood of their dwellings, the mud in which the piles were driven and the peat formed about the sites, let us into the secret of their habits and arts, for here is a museum of specimens illustrative of the lake-dwellers' environment. They were fishermen and hunters, using nets and bone hooks of excellent make; but, more important still, they domesticated animals—the sheep, goat, ox, and pig, whose manure in some cases forms thick deposits on the platforms where they were herded; they cultivated wheat and barley, spun hemp upon primitive looms, and made use of the dog in guarding their homes and herds. Their artistic faculty expressed itself in the admirable design and finish of their fishing, hunting, and agricultural implements and weapons, and pottery was a common article of domestic use. The housewife pounded grain in rough stone querns, and baked cakes, of which some remnants have been found.

Little is known of their physical characters, for, with the exception of the burying-place in the Canton of Vaud, containing fifteen skeletons in a subterranean chamber supported by stones, associated with stone and bronze implements, there are no data from which

to draw any trustworthy conclusions. This sepulchre is also apparently of modern date in comparison with the earlier lake-dwellers, and still more so in relation to the troglodytes or any other primitive race which may be presumed to have preceded the oldest pile-dwelling builders.

In South America, Africa, New Guinea, the Philippines, and some other islands of that archipelago, we have interesting testimony to the similarity of habits in uncultivated races, whose geographical position is a bar to the common origin of their arts. A lake-dwelling in the Philippines or Papua differs in no essential from the ancient structures in Switzerland and Ireland, and the most critical of archæologists would often find it extremely difficult to select, from a collection of implements, the stone axe which came from the hand of a living Melanesian Islander, and one exhumed from the mud of a European lake. Man, indeed, chooses similar materials, impresses upon them the same forms, and fashions them under mental impulses common to the whole species, undirected by aught except those subtle instincts which seem ever to urge him to mould external conditions to his own advantage.

We have no means of judging how long man may remain either in the rough or the polished stone condition of civilization. In Europe, at all events, the periods of rough and polished stone seem to have been separated by a long interval. If a complete series of implements of Palæolithic character be compared with another series of Neolithic character, and the animals

contemporary with each series brought into comparison, a great chasm will be apparent, which we have as yet no means of bridging. No existing savage race can be said to be entirely in the Palæolithic age, while the great majority are far advanced in the Neolithic, and a few are emerging from it and advancing to a higher grade. Although the increase of population among savages is very low compared with civilized people, Africa and Oceania alone contain an enormous number of human beings, implying a long period of occupation; and how vast must be the interval of time necessary to bring them into the condition of the ancient Mexicans and Peruvians, who, in the sixteenth century, had not abandoned their stone implements made of volcanic obsidian, acquainted as they were with the art of working copper and gold!

That all savages might, and must eventually rise to the highest grades of civilization, would not seem probable if we did not know that their history had had its almost exact counterpart among those nations which we regard as the highest exponents of human advancement. Beneath the ruins of Assyria and Egypt, and the monuments of ancient dynasties in China and India, lie still older ruins—the stone implements of an infinitely more primitive people. On the very site of Troy, Dr. Schliemann discovered the industrial remains of a race who fought with stone-tipped spears and arrows. Under those battle-fields where mailed Greeks met in deadly encounter, lay the rude weapons of a race so much older than the Homeric heroes that not a legend

or tradition of their existence survived long enough to become embodied in the literature of their successors. A small colony of lake-dwellers seems to have existed even down to Romano-British times in the heart of London itself; for Colonel Lane Fox has described the remains of one of these settlements in the peaty marsh where Finsbury now stands.

In the Western hemisphere, Peru, Mexico, Califorina, and even Easter Island, far away in the Pacific Ocean, furnish testimony to the universality of a stone period,

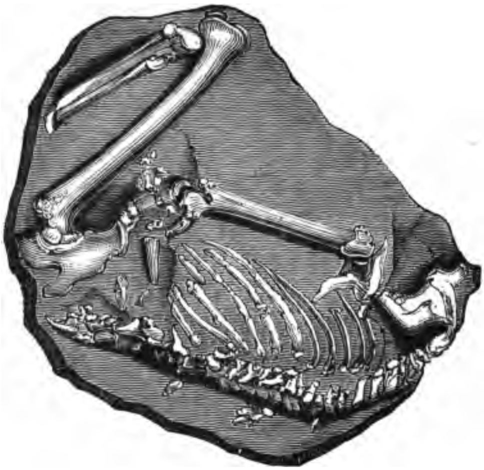

Fig. 42.—Human Fossil; from the Guadaloupe breccia.

and the skeletons embedded in the Guadaloupe limestone breccia would seem, from their association with articles of primitive workmanship, to have belonged to this period, whether they are regarded as truly prehistoric or a comparatively recent tribe of Caribs. If,

as has been asserted, the limestone matrix of these fossils forms somewhat rapidly by the action of the sea casting up fragments of shells, their age may be only a few hundreds of years, or possibly less. Two circumstances combine to throw doubt upon their extreme age. Land and marine shells of species still existing in the islands enter into the composition of this breccia, and Sir H. Davy's analysis of part of one of the bones revealed the presence of some of the original animal matter with all the phosphate of lime. One specimen is in the British Museum collection, and another in Paris. No crania, unfortunately, exist, otherwise it would have been possible to ascertain whether these were Caribs, who practised artificial deformation of the cranium by compression of the frontal region. The example at Paris retains the lower half of the left jaw with two teeth, and a small portion of the upper, the spine, several ribs, one humerus, one femur, and part of one tibia and fibula, with fragments of wrist and finger bones—the skeleton being very much bent. The British Museum example, on the other hand, is extended on the back, and the skeleton has plainly undergone violent dislocation in the region of the chest. A considerable portion of the backbone, a number of the ribs, the pelvis, both thighs, and the lower leg-bones, together with one forearm and part of the hand, are well preserved, but the head is absent. This is altogether a striking fossil, as it exhibits the human figure in an unmistakable manner to the uninstructed eye.

The disclosures made in South-Western Colorado,

North-Western New Mexico, and North-Eastern Arizona, by the United States' Geological Survey, point to the great antiquity of man on the American continent. In one of the dry water-courses of the Chaco cañon, are the remnants of an ancient civilization. Fourteen feet below the surface is a layer of pottery, indicating one era of occupation; ten feet above this, the foundations of buildings, upon a layer of gravel and sand; and over this again the alluvial soil, on which another series of structures was raised—the houses of the famous "cliff-dwellers," whose ruins alone remain. A human skull, too, filled with sand, which has now become stone, comes to light in the pottery layer, beneath the *debris* of two distinct eras of occupation. This deposit could obviously have been formed in the space of half a century; but here we have the works of man in three successive periods, implying not only slow deposition, but the growth and decay of three separate civilizations, the latest of which even consists only of ruins; and not a shadow of tradition respecting the last race of builders survived among the houseless, wandering Indians who occupied this region when it first became known to Europeans.

It would not, perhaps, be an extravagant demand on historical time if an antiquity equal to that of any ruins in the Old World were assigned to these relics of civilization in America; but the record seems to go immensely further back. Agassiz, though by no means prone to exaggerated views of the antiquity of man, estimated the age of the human remains found in the

conglomerate of the Florida coral-reef at 10,000 years. Among other instances, in which we have reason to infer, from physical conditions, that the relics of human industry denote the existence of races in America long anterior to the civilized people made known to us by the Spanish conquests, is the human skeleton discovered beneath four strata of forest growths in the delta of the Mississippi, by Dr. Dowler, who, from an examination of all the circumstances, concludes that 50,000 years have passed away since that ancient man breathed the breath of life!

These remains bring us to the last of the direct and indirect evidences of man in a fossil state. It must be admitted that they are not very numerous, neither do they place the human species absolutely very far back in palæontological chronology. Nevertheless, the considerable changes which are shown to have taken place in the physical features of Devonshire and the Dordogne since the era of the cave men, and man's association with fossil animals, remove him far beyond the utmost limits of history or tradition. As to the problem of his physical origin, much must be done before that can be satisfactorily worked out. Hæckel sums up in a few words that which represents the most advanced opinion on a question which can only be discussed at all from a scientific stand-point: "The series of diverse forms which every individual of a species passes through, from the earliest dawn of its existence, is simply a short and rapid recapitulation of the series of specific multiple forms through which its progenitors have passed, the ancestors

of the existing species, throughout the enormous duration of geological periods." A species has no existence considered in relation to time, no absolute beginning, no fixedness; but the concrete form, which is a small part of a great series, may pass utterly out of being, not, however, without bequeathing a legacy of higher organization to succeeding generations. Immense as man's intellectual pre-eminence is, this cannot logically be held to take him out of the zoological series, while, specially and generally, he is in so many points structurally inferior to other mammalia both near to and far distant from him in the scale. Highly specialized as he becomes at the end of the long term of twenty years devoted to the slow elaboration of his most characteristic organs, he has in the embryonic stage represented some of the lower vertebrates—reptiles and birds. Notwithstanding the prolonged period of gestation, he always makes his appearance in the world as helpless a being as a young marsupial, and frequently devoid of those very mental powers which constitute his chief distinction from lower forms. That which he was at one period in the womb he often remains throughout the whole of life, —a creature arrested at a point of development which does not entitle him to rank higher than some fully expanded organism far lower down in the scale.

All we know of his history teaches us that for innumerable ages he lived the life of a wild beast, and made no more impression on the earth than one of the victims of his well-aimed stone or flint-pointed spear, when all his knowledge—accurate observation of the

habits of the intended quarry—was shared equally by those creatures in the pursuit of their prey. Now he is one of the great geographical forces, consciously and unconsciously modifying the climate of the earth, influencing the distribution and extermination of species, and obliterating the last traces of his immediate barbarian origin in every quarter of the globe. The future teems with problems for his solution—some fraught with danger, others with promise of still higher advancement; but neither can the one be averted nor the other realized except by the full exercise of those faculties to which he owes his present position, by the frankest admission of the claims science justly advances to a thorough investigation of all natural phenomena, and by according an unbiassed hearing to its deductions from them.

> "Yet all these were, when no Man did them know,
> Yet have from wisest Ages hidden beene;
> And later Times thinges more unknowne shall show.
> Why, then, should witlesse Man so much misweene,
> That nothing is, but that which he hath seene?"

THE END.

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